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Canada

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Vegetation Management: An Integrated Approach Proceedings of the Fourth Annual Vegetation Management Workshop

November 14 - 16, 1989
Vancouver, B.C.

Compiled by
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FOREWORD

This workshop, Vegetation Management: an integrated approach was held on November 14-16, 1989 in Vancouver, B.C. The workshop featured oral presentations, posters, demonstrations of computer tools and discussion groups.

The theme was an integrated approach to vegetation management and discussions focussed on the myriad of factors that must be considered in developing vegetation management prescriptions.

Speakers were invited to present papers on two themes – 1) Long term implications of vegetation management, and 2) Vegetation management in salal ecosystems.

Posters addressing a range of issues including competition and vegetation dynamics, vegetation control and seedling response, microclimate conditions, floodplain management and natural regeneration were also presented.

A number of computer tools, ranging from information bases to simulation models were demonstrated.

The workshop featured two discussion groups – one addressing key issues in vegetation management and a second on management of alluvial ecosystems.

Special thanks are extended to the organizing committee members including Alison Nicholson, Dave Spittlehouse, Andy MacKinnon, Phil Comeau, – who organized the computer tools component and Susan Watts, – who organized the poster session. Kathy Banky was responsible for logistical considerations. Thanks are extended to Dan Lousier, Caroline Caza, Bryce Bancroft, Doug Kelly, Craig DeLong, Christian Messier, Maureen Ketcheson, Alison Nicholson, John Karakatsoulis, Pierre Beaudry and Roberta Parish who assisted greatly by facilitating the discussion groups. Lastly, I would like to extend my appreciation to Donald McLennan for the excellent job he did in organizing the alluvial site discussion group.

Funding for the workshop was provided in part by the Canada-British Columbia Forest Resource Development Agreement (FRDA) and the Research Branch of the Ministry of Forests.

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INVITED PAPERS

Long-term Management Issues

The Implications of Vegetation Management on Growth and Yield in Mixed Conifer Forests in the Inland Northwest

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The implications of treatments to reduce the effects of vegetation competition (or interference) on conifers of the Inland Northwest United States are many and varied. During the past few decades a great deal has been learned from research and operational applications of various treatments designed to reduce competition and enhance the performance of planted and natural conifer regeneration. Responses vary from (1) short-term (<10 years) increases in conifer production of up to 17-fold, through (2) no response to (3) observed, and sometimes measured, counter-productive side effects.

From 1977 to 1984, the Intermountain Research Station (USFS), in co-operation with various land management agencies, established studies on approximately 55 sites involving some 70 000 study trees. Research and operational experience of other organizations, particularly Potlatch Corporation and Champion International, has added to this pool of information. Much of this experience is catalogued in Boyd *et al.* (1985). Formal establishment of studies involving herbicides by the Research Station (and by Potlatch Corporation) was terminated in 1985 and 1986. Data are being archived (and updated when special funding is supplied) by the Station and the University of Idaho. Champion International has maintained an active program of chemical vegetation management research and operational use. A co-operative *Vegetation Management Working Group* provides for exchange of information through a University of Idaho sponsored information centre.

In the northern Rocky Mountains and in adjacent areas, a tool is available for predicting the effects of vegetation management treatments on end-of-rotation production from short-term survival, growth, and mortality measurements. This tool is the Prognosis Model for Stand Development (Stage 1973; Wykoff *et al.* 1982) and its various added components and extensions. The Regeneration Establishment Model (Ferguson and Crookston 1984; Ferguson *et al.* 1986) adds planting and site preparation (with the implied competition effects) by burning and mechanical means to the treatments that can be accounted for, or to PROGNOSIS. The program CHEAPO (Horn *et al.* 1986) provides an extension of Prognosis to include economic values. COVER (Moeur 1985) provides a means of estimating height and cover of shrubs in forest stands. Stage and Boyd (1987) describe procedures for projection of short-term tree responses to competition reduction to end-of-rotation production.

Essential to any vegetation management program is the acquisition of conifer response information for a variety of conifer species in the range of environments representative of the management unit. Such data should help to define those environments in which there is a problem and an opportunity for improvement of conifer performance. Projection procedures require data, both from experimental trials which are very carefully conducted and measured, but of limited time, geographical, and environmental range, and also from operational applications which span a range of time, geography and environments. Much of our experience in vegetation management was recently reported in Baumgartner *et al.* 1986.

My experiences lead me to advocate (1) chemical site preparation as the most environmentally gentle of all treatments, (2) spot treatment where physically possible, (3) fallow type chemical site preparation in lieu of concurrent treatment, (4) careful consideration of the reaction of native and introduced herbivores to vegetation management treatments, and (5) monitoring of operational treatments, along with representative untreated stands or trees, to provide additional response data.

Our experience has shown that management of competition is not as simplistic in forestry as it is in agriculture. The silviculturist is dealing with more than "crop" and "weed" relationships. Our forests are a complex ecosystem involving a number of herbivores that are dependent on the competing vegetation for food and cover. Pathogens may proliferate on the underground carcasses of the weeds we kill. Mycorrhizal fungi may be affected by chemical vegetation management. We have circumstantial and/or anecdotal evidence that snowshoe hares, pocket gophers and grasshoppers will kill and damage trees in stands where their main food supply has been severely depleted by vegetation management efforts. We suspect that this same effect might occur with big game and domestic livestock. Killed competing vegetation may supply the substrate for proliferation of damaging pathogens such as armillaria root rot. At present we lack knowledge on what chemical treatments might do to mycorrhizal development and to symbiotic and non-symbiotic nitrogen fixation.

REFERENCES

Baumgartner, M., R.J. Boyd, D.W. Breuer, and D.L. Miller. 1985. Weed control for forest productivity in the Interior West. Wash. State Univ., Coop. Extens., Pullman, Wash. 148 p.

Boyd, R.J., D.L. Miller, F.A. Kidd, and C.P. Ritter. 1985. Herbicides for forest weed control in the Inland Northwest: a summary of effects on weeds and conifers. U.S. Dep. Agric. For. Serv., Intermount. Res. Sta., Ogden, Utah. Gen. Tech. Rep. INT-195. 66 p.

Ferguson, D.E. and N.L. Crookston. 1984. User's guide to the Regeneration Establishment Model: a Prognosis Model extension. U.S. Dep. Agric. For. Serv., Intermount. For. Range Exp. Sta., Ogden, Utah. Gen. Tech. Rep. INT-161. 23 p.

Ferguson, D.E., A.R. Stage, and R.J. Boyd. 1986. Predicting regeneration in the grand fir-cedar-hemlock ecosystem of the northern Rocky Mountains. For. Sci. Monogr. 26. 41 p.

Horn, J.E., E.L. Medema, and E.G. Schuster. 1986. User's guide to CHEAPO II: economic analysis of Stand Prognosis Model outputs. U.S. Dep. Agric. For. Serv., Intermount. Res. Sta., Ogden, Utah. Gen. Tech. Rep. INT-211. 38 p.

Moeur, M. 1985. Cover: a user's guide to the canopy and shrubs extension of the Stand Prognosis Model. U.S. Dep. Agric. For. Serv., Intermount. Res. Sta., Ogden, Utah. 49 p.

Stage, R. 1973. Prognosis model for stand development. U.S. Dep. Agric. For. Serv., Intermount. For. Range Exp. Sta., Ogden, Utah. Res. Pap. INT-137. 32 p.

Stage, A.R. and R.J. Boyd. 1987. Evaluation of growth and yield responses to vegetation management of the mixed-conifer forests in the Inland Northwest. *In* Forest vegetation management for conifer production. J.D. Walstad and P.J. Kuch (editors). John Wiley and Sons, Inc., New York, N.Y. Chap. 10.

Wykoff, W.R., N.L. Crookston, and A.R. Stage. 1982. User's guide to the Stand Prognosis Model. U.S. Dep. Agric. For. Serv., Intermount. For. Range Exp. Sta., Ogden, Utah. Gen. Tech. Rep. INT-133. 112 p.

Vegetation Management and Public Issues in the Pacific Northwest

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LOCATION AND SETTING

The Siuslaw National Forest is located in the central portion of the Oregon Coast Range. The headquarters (supervisor's office) is located in Corvallis, Oregon, with Ranger District offices located at Hebo, Mapleton, Alsea, and Waldport. The general crest of the Coast Range is 457 m above sea level, though some peaks are higher, with a few over 610 m. The topography consists of a complex ridge system characterized by short, steep slopes.

The Forest has a maritime climate. Average annual precipitation varies from 203 cm at the coast to 305 cm at higher elevations. Although some snow falls, it is usually limited to elevations greater than 610 m.

The Forest contains some of the most productive lands for conifer production in the world. The average Douglas-fir (*Pseudotsuga menziesii*) site index (100-year base) is 49 m (161 ft). This site index is generally uniform throughout the Forest. The Siuslaw falls within the western hemlock (*Tsuga heterophylla*) Zone as described by Franklin and Dyrness (1973). The major tree species is Douglas-fir; however, the Forest also supports major volumes of Sitka spruce (*Picea sitchensis*) and western hemlock. The principal hardwood species is red alder (*Alnus rubra*), with a small component of bigleaf maple (*Acer macrophyllum*).

One objective of land management on the Forest is to continue supplying our share of national timber needs. In 1988, the Siuslaw National Forest contributed approximately 3% of the volume provided from the entire National Forest System.

The normal method of regeneration harvest is clearcutting. Following harvest, the principal silvicultural objective is to establish new plantations with 600-750 uniformly spaced stems per hectare at a stand age of 10 years. We normally plant between 850-1000 seedlings per hectare. With proper animal protection, vegetation management, and allowance for seedling mortality, we are able to meet this objective.

Over the last 5 years an average of 2377 ha per year have been reforested by planting. Approximately 55% of the sites were prepared by broadcast burning and 45% required no site preparation. On about 379 ha the vegetation was hand-slashed before broadcast burning. In addition, we have treated 1645 ha/yr for release.

Following planting, vegetative competition occurs during two distinct periods on approximately 60% of the Forest. These are: (1) during plantation age 2-4 years, when salmonberry (*Rubus spectabilis*) is the major competitor; and (2) usually at a stand age of 5-8 years, red alder becomes a major competitor when it overtops Douglas-fir seedlings. On the balance of the Forest, competitive vegetation is not a major problem.

LIFE BEFORE THE HERBICIDE WAR

Prior to 1984, the Forest totally relied on the use of herbicides for site preparation and release treatments. Herbicides were also used for noxious weed control, roadside vegetation control, and facility maintenance. Only minor areas were treated using other methods, and then only on lands where non-chemical methods had to be used (e.g., fish hatchery watersheds or domestic watersheds). We did not know much about non-chemical methods, but the general belief was they "would not work."

Some of the herbicides we used were 2,4-D, 2,4,5-T, picloram, 2,4-D amine, fosamine, glyphosate, and Amitrole-T. Most of the treatments (except for 2,4-D amine) were done by aerial methods. A typical program averaged 2267 ha/yr.

When public pressure over herbicide use began to increase in the mid-1970's, we took the attitude that "We're right", "We're the professionals", "We know what's best." We took the stance of discounting or discrediting public comments against the use of herbicides, and at times we also discredited the individuals involved.

THE HERBICIDE WAR: START OF PUBLIC PRESSURE

In the Pacific Northwest, the so-called herbicide wars started in earnest in 1976, when a suit was brought against the Forest Service over the use of 2,4,5-T. The plaintiffs in this suit were Citizens Against Toxic Sprays, the Oregon Environmental Council, and Hoedads. As a result of this suit, the judge ruled that the Forest's Environmental Impact Statement was deficient, and the Siuslaw National Forest was enjoined from using 2,4,5-T and Silvex. We rewrote the Environmental Impact Statement and the injunction was later lifted, but every year after this lawsuit our herbicide program was challenged in and out of court.

The complaints against the use of herbicides were many, but the major issues were public health, worker health, effects on fish and wildlife, water quality, and chlorinated compounds in the smoke from burning slash that had been treated with herbicides.

After the first lawsuit, the Forest Service kept on using herbicides with little change in either the program or attitude. We continued to deny that any non-chemical methods would work. We felt that these other methods were too expensive and ineffective and that unacceptable tree mortality would result.

Opponents to the use of herbicides took their case to the news media, as well as to the courts. Although there were plenty of emotional and unscientific statements made on both sides of the issue, there were also a number of scientists of national status who contributed new research information to the debate. Overall, however, the arguments offered by opponents to herbicide use had a stronger public appeal. The debate took on a strong "David and Goliath" aura with the Forest Service being portrayed as Goliath.

The last major battle in the herbicide conflict began in July 1983, when a suit was filed in U.S. District Court for the District of Oregon. (Civil 83-6273-E). The plaintiffs were The Northwest Coalition for Alternatives to Pesticides, Oregon Environmental Council, and Audubon Society of Portland. The defendants were the Secretary of Agriculture, the Secretary of the Interior, and the Administrator of the Environmental Protection Agency.

As a result of this suit, on March 14, 1984, United States District Judge James M. Burns ruled that the defendants had not prepared an adequate Worst Case Analysis pursuant to their National Environmental Policy Act (NEPA) obligations. An injunction against the use of herbicides in the Pacific Northwest Region of the Forest Service (Oregon, Washington, and two counties in Northern California) and Bureau of Land Management (BLM) Districts in the States of Oregon and Washington was issued, to be in effect until agency obligations were fulfilled.

This brought a court-imposed suspension in the use of herbicides on public lands.

On the Siuslaw National Forest, where the use of herbicides was the standard method used in the control of unwanted vegetation, the reality of not having it began to sink in. This realization forced us to find successful non-chemical methods to treat vegetation problems.

INJUNCTION PERIOD (MARCH 1984 - MAY 1989)

Although some non-herbicide trials were established before 1984, the injunction pushed our search for alternative methods to the forefront. During the injunction period we developed, and are refining, the following techniques:

1. Slash and burn.
2. Manual control of unwanted vegetation during specified cutting periods.
3. The use of grasses and grazing.
4. Finding the best tree to outplant by looking at different seedling (nursery stock) specifications.
5. Defining the tolerable limit of vegetation competition before treatment.

We have determined that for plantation management, some operations (i.e., site preparation and repeated salmonberry treatments) are more expensive now than when treatment was accomplished with herbicides. On other areas where only one treatment is necessary, costs are often lower without herbicides. Additional expenses accrue on sites where more than one treatment is necessary. We have been experiencing increased treatment costs of $30-$300/acre. The difference depends on site conditions, weather variables, timing of treatments, and air-quality conditions. In addition, the cost of herbicide application is much higher on the Siuslaw National Forest than on nearby private lands, as a result of potential and actual public conflict and the scale of operation.

To date, the Siuslaw National Forest has not lost any plantations to vegetative competition. Although some costs have increased and some decreases in growth are occurring, no reforestation or release backlog has developed on the forest.

In 1988, the Forest Service completed a new Environmental Impact Statement for vegetation management which resulted in the lifting of the injunction. However, we are presently under an administrative stay, imposed by the Chief of the Forest Service, which prohibits our use of herbicides. Eventually, we should again have the use of herbicides, but only when other methods would not be effective or where their costs would be unreasonable.

Although we can manage without the use of herbicides, the Siuslaw National Forest would consider using them under certain situations, primarily in areas where alternative methods are proving ineffective or inordinately expensive. Some examples are: reforesting areas adjacent to roadsides where the salmonberry is very dense; reforesting the portion of plantations on lower concave slope positions (generally on north aspects); and reforesting in smoke sensitive areas as a tradeoff for broadcast burning.

WHAT WE HAVE LEARNED

We have learned much. Some of the points are summarized below:

1. Listen to your public and learn how to work with them.
2. Public opinion will affect management of public lands and resources.

3. A few dedicated people (one or two) can be a powerful enough "public" to stop a program under United States laws and regulations.
4. Do not put on the "blinders."
5. Work with research to develop alternative methods of treatment. Practicing foresters, universities, researchers, and environmentalists have to start communicating to find solutions. For example, this paper was reviewed with comments by Mary O'Brien, staff scientist and former plaintiff from The Northwest Coalition for Alternatives to Pesticides.
6. Document your practices: keep records of what's going on, what works, what doesn't work, etc.

CONCLUSION: A PREDICTION OR TWO

First, public scrutiny of management practices in the field of forestry is increasing and will continue to increase. Current forestry issues in the northwest include the Northern spotted owl, old growth, herbicides, clearcutting, air quality, and human health. More issues seem to emerge each year.

Second, if a public land management agency goes to court over one of these issues, it will often lose. It will *certainly* lose in the public relations arena.

Third, the herbicide issue has not gone away. I understand that it is moving north! Any program you propose is likely to be challenged.

To get prepared for the eventual challenge to your herbicide program, I offer the following suggestions:

1. Begin research for alternative methods.
2. Begin documenting current results.
3. Start talking with your public. Involve them from the beginning and keep talking with them throughout the program.
4. If you are not involving your public – begin now.

Vegetation Management and Public Concerns in British Columbia

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Vegetation management means different things to different people. Foresters understand that it is possible and desirable to manipulate a vegetation complex in a way that will favour our anticipated crop. This generally means that competing vegetation will be controlled to allow the maximum survival and growth of the lucky conifer that we have designated as a crop tree. Our objectives are straightforward and simple in this regard, but very quickly we find that our objectives are not necessarily shared by everyone else. Vegetation that we might consider to be a competitor is very often the critical forage resource to the wildlife biologist or the critical habitat resource of a habitat biologist. It may even be the scenic resource of a casual recreationist. Or it might be all of these at the same time. Vegetation management is, therefore, in the eyes of the beholder, and these days there are more and more eyes watching very closely.

The public in British Columbia is the owner of the forest resource. This paramount fact colours all aspects of forestry in the province. The basic tenet in forest management is that the objectives of the owner must be satisfied. In the past, forest harvesting was able to proceed relatively unfettered because there seemed to be an unlimited forest, access was poor, and the public was not as ecologically and environmentally aware. Today this has changed dramatically! Forest practices are under critical attack from a highly educated and concerned public. The benefit of this is that forest management will adapt and change as they better reflect the objectives of the forest owners. The difficulty is that forest managers must adapt and change as well. The most difficult thing, for some, will be the necessary shift in our thinking and perceptions of what we are and what we do.

Clearly the public is beginning to think about their forests and they are thinking of them as much more than simply the warehouse for lumber. Resource values such as clean water, clean air, an aesthetically pleasing landscape, and a habitat which maintains the natural diversity of the biotic world are becoming the focus. These objectives are very subjective, very difficult to quantify, and very difficult to manage for, but they are central to overall forest management.

Vegetation management, in large measure, can be seen as a key actor in this very complex play. Certainly the public perceives it as such, since some of their most vocal opposition has been directed at this component of forest management, especially where herbicides are used. The need for any type of vegetation management is predicated on the desire for more and more wood products from a shrinking forest land base over shortening rotations. This has put enormous pressures onto forest managers to compress Nature's lifecycles into Man's impatient timeframes. Many members of the public believe that our present management practices, such as vegetation manipulation, are simply the result of a mistaken land and forest ethic. And some forest managers have positioned themselves in clear opposition by steadfastly asserting that all is well in the forest.

People who are concerned, or worse, afraid, for their future and their children's future because of present forest practices are not necessarily wrong or right. But they are still concerned. The public still owns the forest and has the right to define its objectives for the forest as it sees fit. This process is occurring today as forest managers are presented with clear opposition to much of their vegetation management practices. For now the public is vocal about what it *does not* want. Over time it will move beyond this and begin to define that which it *does* want. Forest managers must actively encourage this

process and support it where they can. Denying the public's legitimate concerns will not work any longer; restricting their legitimate role in controlling their own resource cannot happen any longer. Today's forestry must be practiced in co-operation and consultation with all of the forest users. Vegetation management is no exception.

The Other Choice: Managing Red Alder

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Foresters of the Pacific Northwest have worked for 30 years to rid their conifer plantations of red alder (*Alnus rubra*). In large part, these efforts have been successful. So why are we talking about growing alder on purpose? Aren't conifers what we want to grow? Of course they are. But there may be some sites and some situations where growing alder does make sense.

The value of alder has risen steadily for the last 5 years. Prices in British Columbia do not equal those received in the U.S. However, the trends in the U.S. indicate that prices in British Columbia will continue to rise well above their current levels. The high standing volume of alder found in this province also indicates that markets will continue to improve: industries develop where there is sufficient raw material.

In addition to these economic reasons for growing red alder, regeneration of alder may be far easier than conifer regeneration under some conditions. These may be sites that are moist, sites infected with laminated root rot, sites with abundant red alder seed sources, or sites with other difficult brush problems. Red alder does require less weed control than conifers for successful regeneration.

SITE REQUIREMENTS

What are good red alder sites? Alder does not tolerate much flooding. It falls between Douglas-fir and redcedar in flood tolerance. It does not grow well on dry sites. If the Douglas-fir site class is less than III because moisture is limiting, it is not a good alder site. A unit that is less than III because of nutrient limitations may still be a good alder site because alder can fix nitrogen. Alder is less tolerant of cold than Douglas-fir. A rough upper limit of 600 m may be appropriate for commercial production.

REGENERATION

Red alder can be regenerated from seed or planted seedlings. While we can all think of examples of alder regenerating from seed, little has been done on deliberately doing so. We have more experience with planting seedlings. The bottom line is that planting is to be greatly preferred.

Regeneration from seed Alder seed falls in late autumn and through the winter. Most seed falls during dry periods, which usually occur when we have north or east winds. Consequently, the seed source for regenerating a harvest unit should be on the north and/or east side of the unit. There is some variation in seed production from year to year. However, successful seedling establishment can continue for several years, so these variations are not considered to be important.

Careful site preparation is essential. Alder requires disturbance of the soil organic layer for successful establishment. This can take the form of mixing of organic layers with the mineral soil or complete removal. Because the pattern of disturbance determines the pattern of tree establishment, a homogenous pattern is important. An even pattern of tree spacing will produce straighter trees.

The shortcomings of seed regeneration are (1) the high density produced, which necessitates later spacing operations, and (2) the crooked trees that result from the irregular spacing and high density. This reduces tree value.

Seedling regeneration Seedling regeneration begins with seed collection. Instructions are now available on seed zones and seed collection, handling, and processing. There are some opportunities for improved tree growth with careful selection of seed source.

Survival and growth studies show that bareroot seedlings outperform container stock. Nursery bed spacing is critical to seedling quality. Seedlings should have a minimum caliper of 4 mm and a minimum height of 40 cm, with large buds down the entire stem.

As with all tree seedlings, less competition from weeds means more growth for alder. However, because potential initial growth rates are so high, alder seedlings can get free of competition much faster than conifer seedlings. This means that growth reductions will only be short term and "brush-bashing" that occurs during harvest may be sufficient for reliable establishment. However, growth will probably be better with less weed competition.

Newly planted alder seedlings are very frost-sensitive so planting is generally done later than conifer planting. Plant as late as possible to avoid spring frosts; plant before the rains stop. In Oregon and southern Washington, the planting window is between mid-March and mid-April.

DENSITY MANAGEMENT

Density management plays two roles, (1) maintaining rapid tree growth and (2) producing straight boles. Density management guides are available to prescribe target densities. The issue still in question is timing of spacing.

Principles of hardwood thinning differ from conifer principles because the value of a tree is in the stem below the crown and in the proportion of clear wood in the stem. Early spacing (age 0-5) combined with later pruning (age 8-15) will produce straight trees with a high percentage of clear wood. A 30 cm dbh tree can be grown in 20-25 years. Later spacing (age 12-16) allows natural branch pruning to remove branches yet can lengthen rotations to 30-35 years. The percentage of clear wood is reduced because the knotty core is larger. Later spacings also result in trees with more crook. Thinning after about age 17-20 (depends on site) will result in less thinning response because height growth rate is dwindling rapidly in these "old" trees.

Wildlife Concerns: Biodiversity - Don't Leave the Forest Without it

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The management of natural ecosystems can have a significant impact on biological diversity. Biodiversity is an umbrella term which describes nature's variety, including both the number and frequency of ecosystems, species, or genes in a given assemblage. Maintenance of biological diversity (wildlife species) and their habitats is the major goal of the Wildlife Program. The major concern the Wildlife Branch has with vegetation management is the potential to change and reduce existing biological diversity provincially, regionally, and at the stand level. Maintaining biodiversity is a crucial concern in management of renewable natural resources. It is vital, to ensure both the sustainable productivity of most wildlife species that we currently value as resources, and the long-term health of ecological systems that must provide these resources for future generations. Concern for biodiversity is fundamental to caring for the land and establishing a land ethic (Salwasser 1989). For the purpose of this paper, the term vegetation management includes all forms of forestry, from harvesting and site preparation, to stand tending and protection activities.

HARVESTING AND BIODIVERSITY

Forestry practices in general and vegetation management in particular can have a significant effect on biological diversity. Logging can increase biological diversity by creating a higher proportion of openings, edge, and early successional habitats than is found in some of the natural stands. This increase in diversity is beneficial to certain early successional species and species that use habitat edge (e.g., some vole species, some birds, and some ungulates such as elk, deer, and moose). Logging will decrease the size of the remaining blocks of undisturbed forest. Species that use late successional habitats (e.g., marten, goshawk, and caribou) are a concern, as these are at risk of being eliminated from the biological diversity mosaic. Logging is also accompanied by other disturbances, such as roads and human intrusion, which are harmful to certain species such as grizzly bear and caribou (Wilcove 1988; Rice 1989). Wildlife species dependent on old-growth forest are selected against over time as the old-growth forests are harvested and ultimately biodiversity is reduced. Consequently, to maintain biodiversity at all levels it is necessary to maintain some representative old-growth ecosystems with priority given to areas supporting red-listed and blue-listed wildlife species that depend on old-growth habitat.

SITE PREPARATION AND BIODIVERSITY

Herbicide treatments can lead to reduction of diversity by reducing abundance of some plant species and by truncating the natural duration of early seral stages. When high habitat values are involved, such as on floodplains and riparian areas for grizzly bear and elk, consideration should be given to measures that maintain understory forage. For example, the "free to grow" time frame might be extended or stocking standards might be reduced to maintain wildlife forage well into the next rotation.

PLANTING AND BIODIVERSITY

The management of stands to produce a few currently commercially valuable tree species could lead to forest simplification and a reduction in the ecosystem diversity and biodiversity. Aspen and alder are currently treated as weed species on most sites, but play important roles in contributing to biodiversity. The role of alder in nitrogen fixation within the ecosystem may be very important for both terrestrial and aquatic ecosystems over the natural successional cycle. Aspen also provides habitat for many cavity nesting birds and browse for species such as elk.

CUMULATIVE EFFECTS AND BIODIVERSITY

Each of the concerns mentioned above may not appear to be significant in some areas. However, collectively and over time, they lead to forest simplification and loss of biodiversity. There is cause for serious concern, since many of the practices contributing to forest simplification are promoted by present government policies that narrowly pursue a single purpose, such as intensive silviculture and forestry on many sites. These policies need to be re-examined. Intensive forestry needs to be carried out on some areas to meet the increasing demands for wood products, but it should not be done at the expense of maintaining healthy diverse ecosystems.

WHAT CAN BE DONE TO MAINTAIN BIODIVERSITY?

By examining vegetation management practices, foresters and land managers can probably determine where some significant gains for maintaining biodiversity can be made. Often these will be at very little real cost in time, effort, or expense. For example, ensuring that there is a good distribution of wildlife trees (snags) left as a component of stands will maintain habitat for insectivorous birds and mammals, and contribute to a healthy future forest. Similarly, when dealing with areas known to have high wildlife values, treatments must address the supply of forage and cover for the resident wildlife species over time. Stocking types, free-to-grow criteria, and stocking density can be altered to maintain wildlife forage values. Maintenance of riparian zones as special biodiversity areas will help maintain ecosystem diversity and biodiversity.

Maintenance of stand level diversity, such as the structural components, coarse woody debris, snags, and multi-layered canopies can be achieved by varying silvicultural systems used for different stands during harvest and stand tending. Maintenance of coarse woody debris needs to be considered in utilization standards, fire abatement policy, and site preparation. The move towards cleaner logging reduces the coarse woody debris and the diversity of habitats for some small mammals. A variety of logging types and silvicultural systems can enhance or maintain stand-level ecosystem diversity in an area.

Areas with high wildlife values which are in conflict with forest values are a small percentage of the entire forest land base. Foresters have traditionally viewed wildlife and fisheries as non-timber resources. Accordingly, in some areas with high wildlife values, timber should be considered a non-wildlife resource.

Vegetation managers are in a unique position to understand and manage for the elements that maintain ecosystem diversity at the stand, regional, and provincial levels. The Wildlife Program goals for maintaining biological diversity are linked to the management of ecosystem diversity. The benefits of managing for biodiversity will be the maintenance of our rich biological legacy, both flora and fauna, and the assurance that the options for the land base are equal to or greater in the future than the options at present. We are designing the future.

REFERENCES

B.C. Ministry of Environment. 1989. Provincial Wildlife Strategy. Wildlife Branch, Victoria, B.C. Draft report. 124 p.

Cannings, R.A. and A.P. Harcombe (editors). [1990]. The vertebrates of British Columbia: scientific and English names. Royal B.C. Museum Heritage Record and Wildl. Rep., B.C. Min. Tourism, Rec. Culture and Min. Environ., Victoria, B.C. In preparation.

Harris, L. 1984. The fragmented forest. Island biogeography theory and the preservation of biotic diversity. Univ. Chicago Press, Chicago, Ill.

McNeely, J.A. 1988. Economics and biological diversity: developing and using economic incentives to conserve biological resources. International Union for the Conserv. of Nature and Natural Resources. Switzerland.

Rice, R.E. 1989. National forests for the future, policies for the future. Vol. 5. The uncounted costs of logging. The Wilderness Society, Washington, D.C.

Salwasser, H. 1989. Biodiversity: don't leave the forest without it! Habitat Futures. Newsletter of the Wildlife Fisheries Habitat Relationships System. U.S. Dep. Agric. For. Serv., Wildl. Fish Ecology Unit. Utah State Univ., Logan, Utah.

Wilcove, D.S. 1988. National forests for the future, policies for the future. Vol. 2. Protecting biological diversity. The Wilderness Society, Washington, D.C.

INVITED PAPERS

Vegetation Management in Salal Ecosystems

Competition for Nutrients and Chemical Interference by Salal (*Gaultheria shallon* Pursh.)

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Significant evidence has been accumulated to suggest that salal acts as an effective sink for nutrients in clearcuts of old-growth cedar/hemlock stands in coastal British Columbia (Messier and Kimmins 1989; Weetman *et al.* 1989). Salal removal leads to enhanced growth in all species previously growing in association with salal – most significantly with Sitka spruce (Figure 1).

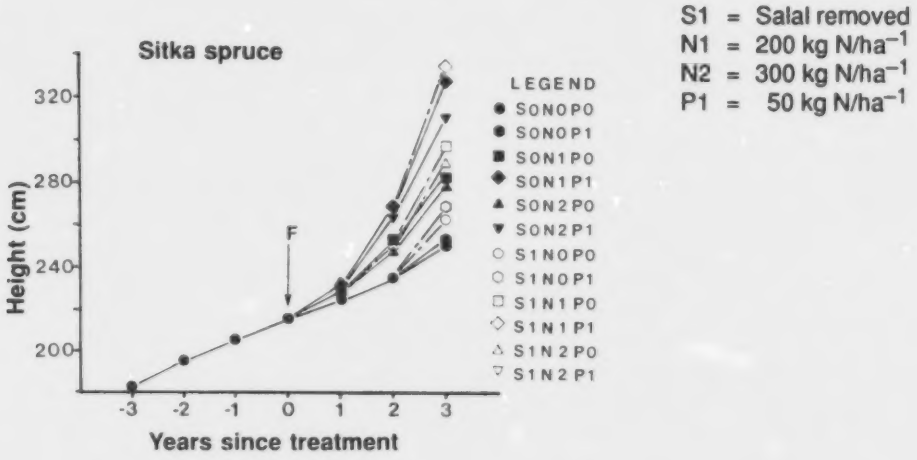

FIGURE 1. Height of Sitka spruce after different treatments (Weetman *et al.* 1989).

The evidence for competition has been more from its manifestations than its mechanisms – by changing resource levels via fertilization, or by manipulating the competitive setting. These studies do not clarify the effect of salal on humification processes and hence soil fertility. Evidence from other studies of the ericaceae has led to the construction of the hypothetical model shown in Figure 2.

Several aspects of this hypothesis are currently being examined. These mechanistic studies are still in preliminary stages, but an examination of nutrient supply using radiotracers suggests that the effect of salal on nutrient uptake restriction is not direct. Rather, there is an effective immobilization of nutrients after clear-cutting and burning which may be due to the effects of salal on humification processes.

CONCLUSIONS

- Competition for nutrients by salal is significant in the early stages of regeneration. Different species show varying degrees of sensitivity.
- The different species response means that site-specific prescriptions for planting and fertilizer requirement be made.

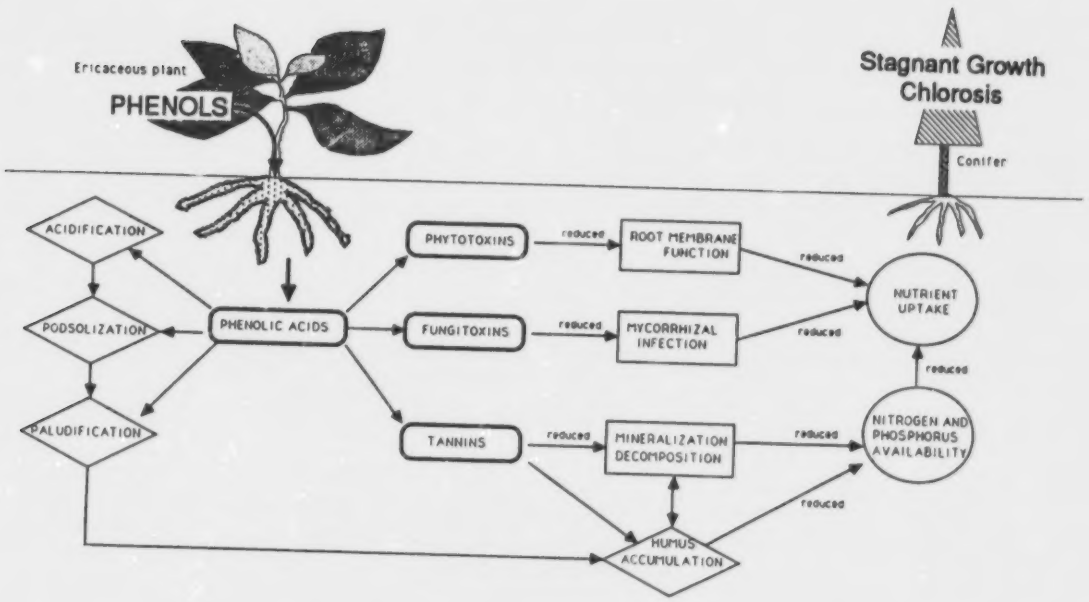

FIGURE 2. Hypothetical model of the effects of ericaceous plants or conifers (de Montigny and Weetman 1989).

OPERATIONAL IMPLICATIONS

Although the effects of salal are not yet clear, experiences with other ericaceous species in other parts of the world suggest that forestry practices that allow the establishment of heathland species result in expensive site-specific efforts at rehabilitation which are rarely fully effective.

Recommendations include:

1. prevention of fires on naturally regenerated cutovers;
2. preparation of seedbeds for prompt natural regeneration; and
3. rapid planting, supplemented where necessary by fertilization.

Messier *et al.* (1989) suggest that salal may not be a problem after canopy closure because of reduced amounts of below-ground biomass. The problem is how to reach canopy closure, but if this stage can be attained it would seem that degeneration to heathland could be prevented.

LITERATURE CITED

de Montigny, L., and G.F. Weetman. [1989]. The effects of ericaceous plants on forest productivity. Proc. IUFRO North. For. Silv. Manage. Working Party (S1.05-12) Symp., St. John's, Newfoundland, August 12-17, 1989. In press.

Messier, C., T.W. Honer, and J.P. Kimmins. [1989]. Photosynthetic photon flux density, red:far-red ratio, and minimum light requirement for survival of *Gaultheria shallon* in western redcedar/western hemlock stands in coastal British Columbia. Can. J. For. Res. In press.

Messier, C. and J.P. Kimmins. [1989]. Nutritional stress in *Picea sitchensis* plantations in coastal British Columbia: the effects of *Gaultheria shallon* and declining soil fertility. (Submitted to Water, Air and Soil Pollution). In press.

Weetman, G.F., R. Fournier, J. Barker, E. Schnorbus-Panozzo and A. Germain. [1989]. Foliar analysis and response of fertilized chlorotic Sitka spruce plantations on salal-dominated cedar-hemlock cutovers on Vancouver Island. Can. J. For. Res. In press.

Factors Affecting Salal Competition For Water

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The physical and physiological processes governing water utilization by plant communities are complex, and the impact of silvicultural treatments such as juvenile spacing and commercial thinning are hard to predict. One ecosystem which has been well studied in British Columbia is Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) on droughty sites with an understory of salal (*Gaultheria shallon* Pursh.). The competitiveness of salal for water is determined by the microclimate and the stomatal characteristics of both the overstory and understory vegetation.

The presence of an overstory of trees significantly alters the microclimate of the understory by intercepting solar radiation and creating turbulence as wind passes over the tree crowns. Denmead (1984) showed that large, turbulent eddies, which originate above tree canopies, can penetrate tree crowns and displace the air surrounding understory vegetation. Stewart (1984) suggested that, as a result of this turbulence, understory vegetation is likely to be exposed to vapour pressure deficits (D) of similar magnitude to those that develop at the tree crown level.

Stomatal resistance (r_s) to water loss from leaves depends largely on plant moisture status and light levels. Plant moisture status is in turn a function of the dryness of the air surrounding the leaves and the ability of plant roots to extract moisture from the soil to replace the water lost through transpiration.

Tan *et al.* (1977) investigated the relationship of r_s to soil water potential and D, for Douglas-fir and salal. As soil water potential decreased and D increased, the r_s of Douglas-fir increased more rapidly than did that of salal. Black and Kelliher (1989) found that the r_s of salal was approximately half that of Douglas-fir, and that the increase in r_s in response to increasing D was only slightly less than that of the Douglas-fir.

MEASURED AND MODELLED WATER USE BY SALAL

Black *et al.* (1980) studied the thinning response of a 30-year-old Douglas-fir plantation, growing on a droughty site but not displaying any signs of nutrient deficiency. Thinning resulted in a poor growth response by the remaining crop trees. Salal, growing as an understory shrub in the thinned stand, was assumed to be competing for the limited soil water. Using a procedure which combined water balance measurements of stand evapotranspiration (E_t) with a simple vapour diffusion model, the researchers estimated that as the fraction of extractable soil water decreased from 0.8 to 0.2, the fraction of total stand E_t originating from the salal understory increased from 40 to 65%. The transpiration rate of trees in the thinned stand was found to be very similar to that of trees in a nearby unthinned stand.

In contrast, Whitehead *et al.* (1984) found that the transpiration rate of individual trees in a thinned Scots pine (*Pinus sylvestris* L.) stand was greater than for trees in an unthinned stand. However, they point out that soil water did not appear to limit transpiration at any time during the year, and the nature of the understory vegetation was not described. Similarly, Brix (1983) found that thinning a Douglas-fir stand resulted in an increase in water availability and basal area increment for the remaining crop trees. These stands were at a much higher density before thinning than those studied by Black *et al.* (1980) and the leaf area of the understory salal was much lower. Consequently, there may have been much greater between-tree competition for water prior to thinning.

Kelliher (1985) examined the effect on the root zone water balance of removing the salal understory from a thinned 31-year-old Douglas-fir stand. The treatment was confined to pairs of trees with root zones isolated by trenching down to bedrock. He found that differences in the root zone water content were small throughout the growing season. Using small lysimeters and porometer measurements in combination with a vapour diffusion model to partition total stand E_t between the Douglas-fir canopy, salal understory, and the forest floor, he estimated the salal transpiration rate to be 0.5-1.0 mm d^{-1} greater than the forest floor evaporation where salal had been removed.

Price *et al.* (1986) measured the stomatal conductance and photosynthetic rate of Douglas-fir growing on plots with the salal understory removed and present. They found that removing salal increased both the stomatal conductance and the photosynthetic capacity of the Douglas-fir needles. They suggested that, while removing salal resulted in only very small differences in root zone water content, these small differences resulted in significantly higher soil water potentials because of the steepness of the soil water retention curve for sandy loam soil, at low water contents. Similar results were observed by Black *et al.* (1985) in a Douglas-fir stand near Nanaimo where salal had been removed from a 30 x 40 m plot. Soil moisture content varied only slightly between the plot where salal had been removed and one in which it was present.

To measure the E_t from a salal understory and the forest floor where salal had been removed, Osberg (1986) constructed a weighing lysimeter containing an undisturbed soil column and salal community. The total stand E_t, for the period June 26 - July 9, was 24 mm of water, or approximately 2 mm d^{-1}. During this same period, measured E_t from the lysimeter varied from 0.60 to 0.84 mm d^{-1}, which was equivalent to between 30 and 42% of the daily total stand water use.

On July 8, the salal growing in the lysimeter was clipped and the soil evaporation rate was measured for 3 days. The mean soil evaporation rate was found to be 0.37 mm d^{-1} This rate was approximately 50% of the mean understory evapotranspiration rate with salal present.

SUMMARY

Black and Spittlehouse (1981) have suggested that thinning stands which experience periodic growing season water deficits may shift water use from the crop trees to the understory shrubs, resulting in a smaller growth response than might otherwise be expected.

Thinning operations on droughty sites should avoid the creation of large gaps in the tree canopy as these gaps act like chimneys, increasing the ventilation below the tree canopy. This can result in the maintenance of larger vapour pressure deficits around understory vegetation. To minimize the number and size of gaps created in the tree canopy, successive light thinning operations are preferable to a single, heavy removal.

This approach may prove to be economically unacceptable, since the economics of thinning operations are strongly related to the number of times a stand must be entered and the harvestable volume available at each entry. However, a single, heavy thinning is also expensive to conduct and the total productivity of the stand may decline because of the failure of the remaining crop trees to exploit the available soil moisture fully.

BIBLIOGRAPHY

Black, T.A., D.T. Price, P.M. Osberg, and D.G. Giles. 1985. Effect of reduction of salal competition on evapotranspiration and growth of early stage Douglas-fir plantations. Contract Research Rep., EP 855. B.C.Min. For., Victoria, B.C.

Black, T.A. and D.L. Spittlehouse. 1981. Modeling the water balance for watershed management. *In* Proc. Symp. Interior West Watershed Manage. April 8-10, 1980. D.M. Baumgartner (editor). Spokane, WA, pp. 117-129.

Black, T.A., C.S. Tan, and J.U. Nnyamah. 1980. Transpiration rate of Douglas-fir trees in thinned and unthinned stands. Can. J. Soil Sci. 60:625-631.

Brix, H. 1983. Effects of thinning and nitrogen fertilization on growth of Douglas-fir: relative contribution of foliage quantity and efficiency. Can. J. For. Res. 13:167-175.

Denmead, O.T. 1984. Plant physiological methods for studying evapotranspiration: problems of telling the forest from the trees. Agric. Wat. Manage. 8:167-189.

Kelliher, F.M. 1985. Salal understory removal effects on the soil water regime and tree transpiration rates in a Douglas-fir forest. Ph.D. thesis. Univ. B.C., Vancouver, B.C.

Osberg, P.M. 1986. Lysimeter measurements of salal understory evapotranspiration and forest soil evaporation after salal removal in a Douglas-fir plantation. M.Sc. thesis. Dep. Soil Sci., Univ. B.C., Vancouver, B.C.

Price, D.T., T.A. Black, and F.M. Kelliher. 1986. Effects of salal understory removal on photosynthetic rate and stomatal conductance of young Douglas-fir trees. Can. J. For. Res. 16:90-97.

Stewart, J.B. 1984. Measurement and prediction of evaporation from forested and agricultural catchments. Agric. Water Manage. 8:1-28.

Tan, C.S., T.A. Black, and J.U. Nnyamah. 1977. Characteristics of stomatal diffusion resistance in a Douglas-fir forest exposed to soil water deficits. Can. J. For. Res. 7:595-604.

Whitehead, D., P.G. Jarvis, and R.H. Waring. 1984. Stomatal conductance, transpiration, and resistance to water uptake in *Pinus sylvestris* spacing experiment. Can. J. For. Res. 14:692-700.

Modeling Salal Growth and Competition

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INTRODUCTION

We have two broad objectives in modeling salal growth and competition: 1) to predict the likelihood of salal (*Gaultheria shallon* Pursh.) competition with crop trees and consequences of management action to that competition; and 2) to aid understanding of the processes underlying competition. Mixed purposes are common in models for management. Although such models are most useful when they are timely, credible, and simple, the model will better reveal appropriate management action if individual processes can be separated. The detail necessary to separate processes may contribute to the credibility of a model but reduces its simplicity. One way for maintaining both credibility and simplicity is the two-track approach of Bunnell (1989a), which separates research and management goals.

RESEARCH AND MANAGEMENT "TRACKS"

Modeling salal growth challenges research because of salal's clonal nature and the near-immortality of an individual genet. Conventional population dynamics modeling, including size-at-age or the -3/2 self-thinning "rule", do not work adequately with salal because plants share resources among ramets and can rely heavily on below-ground reserves (Bunnell 1989b). For most management purposes, however, salal growth can be expressed in terms of biomass per unit area. Major hurdles in modeling competition by salal include the clonal growth form, uncoupling of above- and below-ground biomass, inability to separate discretely some underlying processes (e.g., moisture stress and nutrient uptake), and narrow ranges of available data. The narrow range of available data means models of competition during regeneration cannot be entirely empirically based and must incorporate several untested assumptions.

DATA BASE

Data come from a variety of sites on Vancouver Island and the adjacent mainland in the Coastal Western Hemlock (CWH) zone, and specifically from the CWHa, CWHb1, and CWHb3 subzones. Salal abundance was estimated and related to crop tree growth on 2800 plots. Measures of salal height, abundance, and productivity were measured on an additional 106 plots. A total of 904 salal shoots were aged to estimate growth rates. Current co-operation with other workers at UBC, MacMillan Bloedel, and Western Forest Products will extend this data base.

RESULTS

Results reported here are from the management track and are based on observations rather than assumed relations. Briefly:

1. Although abundant salal does not necessarily indicate competition, abundant salal can reduce basal diameter, height growth, and stocking of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings.

2. Of the potential indices of competition examined (salal height, cover, total biomass, foliar biomass, leaf area, and nitrogen sequestered), salal cover is the simplest and is related to crop tree stocking and height growth on clearcuts, as well as to most other indices of competition. Salal height is a poor index.
3. Salal cover is a poor index of competition in closing stands because it does not necessarily reflect below-ground biomass.
4. Salal develops quickly from rhizomes in the soil after an area has been logged or burned (e.g., Figure 1).
5. Moderate burning delays and reduces salal growth, lengthens the planting window, and reduces competition.
6. Salal can respond positively to thinning but the effect is short lived (Figure 2).

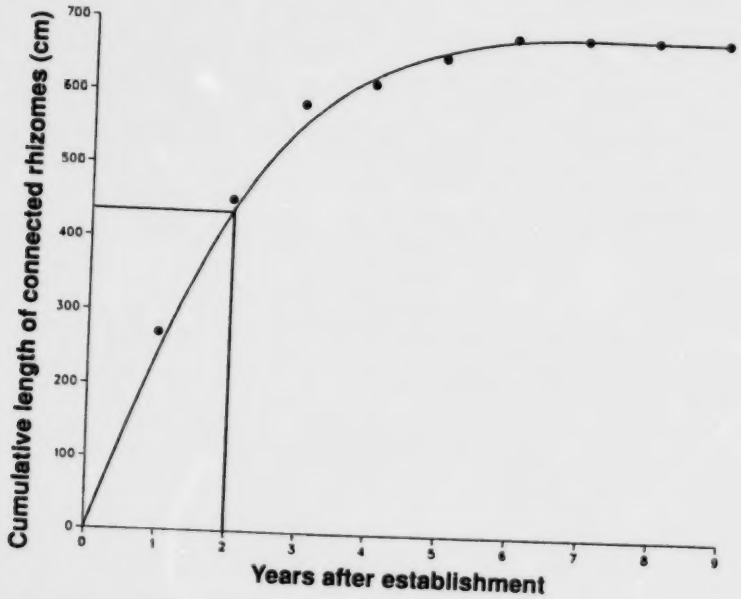

FIGURE 1. Cumulative length of rhizomes interconnecting shoots on eight plants during the first 9 years after establishment of the mother shoots (an index of below-ground competition). Modified from Bunnell 1989b.

OPERATIONAL SIGNIFICANCE

1. Because competition is largely below-ground, it is important that crop trees be vigorous, established early, and well planted.
2. The effective planting window is about 2 years after logging and/or burning (Figure 1).
3. The same moderate burning that reduces salal growth is associated with a positive response by Douglas-fir seedlings.

4. Thinning Douglas-fir stands on drier sites can encourage salal growth, but this growth has little long-term effect on the crop tree (Figure 2).

5. Planting densities necessary to shade out salal quickly are impractically high (Bunnell *et al.* 1989).

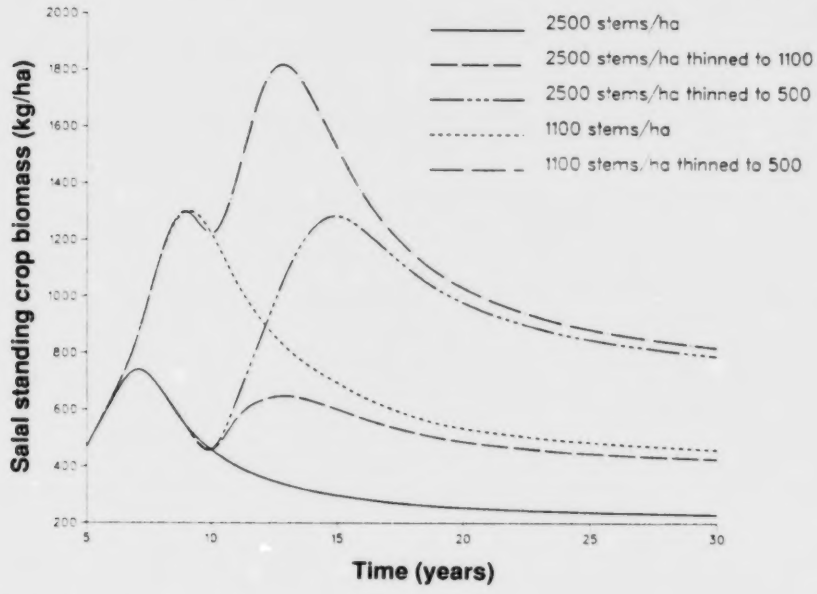

FIGURE 2. Computer simulations using existing data.

LITERATURE CITED

Bunnell, F.L. 1989a. Alchemy and uncertainty: what good are models? U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. PNW-GTR-232.

_____. [1989]b. Salal (*Gaultheria shallon* Pursh.) under forest canopy: reproduction. Can. J. For. Res. In press.

Bunnell, F.L., R.K. McCann, P. Lindop, and C. Messier. [1989]. Salal – a competitor? FRDA pamphlet. In press.

Control of Salal

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Salal is one of the most difficult-to-control competitors to conifer growth in coastal British Columbia forests. It has special adaptations that make it tolerant of many management options: 1) its leaves are thick and leathery, preventing or reducing herbicide translocation through the leaves; 2) its root systems are extensive and can reproduce through layering, sprouting, and suckering; and 3) it is damaged by few insects and diseases.

The following is a summary of salal response to various treatments concentrating on those tested in FRDA 2.17.

HERBICIDES

Above-ground salal growth response to the following treatments were tested:

1. sulfometuron methyl (Oust®) at 0.60 kg in a water (300 L/ha), spring application;
2. hexazinone (Velpar L®) at 4.0 kg applied in water (300 L/ha), spring application;
3. trichlopyr ester (Garlon 4E®) at 4.0 kg applied in diesel (100 L/ha), spring application;
4. triclopyr ester (Garlon 4E®) at 4.0 kg applied in a mineral oil (100 L/ha), spring application;
5. mineral oil (AWK #1®) at 100 L/ha, spring application;
6. triclopyr ester (Garlon 4E®) at 4.0 kg applied in diesel (100 L/ha), late summer application;
7. glyphosate (Vision®) at 4.0 kg applied in water (100 L/ha), late summer application;
8. metsulfuron methyl (Ally®) at 0.12 kg in water (100 L/ha), late summer application;
9. manual removal, repeated hand pulling; and control (no treatment).

First-year results indicated that the spring application of triclopyr ester (Garlon 4E®) at 4.0 kg in diesel (100 L/ha) was the most effective treatment. In an attempt to increase salal control, higher application rates (4.0 and 6.0 kg a.i./ha) and higher diesel carrier volumes (150 and 300 L/ha) were tested in a subsequent trial. In this trial, levels of salal control were higher than achieved initially. The most effective treatment tested (dormant season application of triclopyr at 4 kg a.i./ha in 150 L/ha of diesel oil) reduced salal cover from 41 to 6% 2 years following treatment.

SCARIFICATION

A variety of scarification techniques for controlling salal were tested at two locations on Vancouver Island, Lens Lake and Cameron. The treatments included:

1. **Spot mix** – salal and organic materials were incorporated into the mineral soil within the 1-m^2 treatment areas.
2. **Spot scalp** – salal and organic materials were removed from within the 1-m^2 treatment areas.

3. **Blade scalp** (carried out in only one location) – salal, organic materials, and some surface mineral soil removed by a D-8 Cat and deposited on the side in a berm.

4. **Garlon® 4E** – Double application of Garlon® 4E (site preparation broadcast application followed several months later with a spot treatment to control any surviving salal). The goal of this treatment was to create a salal-free growing environment without disturbing the organic layer.

5. **Control** – no treatment.

At the Cameron location, the repeated Garlon® treatment was most successful, reducing salal cover to 4%. Salal in the scarification treatments recovered to pretreatment levels by the third growing season after treatment. Salal cover in the control more than doubled in three growing seasons to 32%.

At the Lens Lake location, the salal recovered faster than at the Cameron location. Salal reached pretreatment levels after two growing seasons following spot scarification. Salal cover averaged 7% 3 years after repeated Garlon® treatments. The blade-scarified treatment was most successful, reducing salal cover to 6%. Salal cover in the control almost doubled in three growing seasons, averaging 39%.

In summary, 3 years of growth response shows that spot scarification treatments do not provide long-term control of salal. Established root systems of salal surrounding the treated areas contribute to salal recovery as roots grow into the treated areas. The blade scarification treatment, although providing longer-term salal control, is not considered appropriate treatment for these ecosystems because of concerns for site degradation. Although the repeated Garlon® applications provided the highest level of salal control, it is not considered a practical method of salal control. A single herbicide application that is as successful as the double application in this study may prove practical. Site differences will affect salal response to these treatments.

Douglas-fir Response to Salal Control

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INTRODUCTION

Vigorous growth of salal (*Gaultheria shallon*) can create a serious impediment to Douglas-fir regeneration on many mid- to low elevation ecosystems in the Vancouver Forest Region. Poor seedling performance may be associated with competition for water and nutrients, slow decomposition of salal-derived forest floors, and possible allelopathic effects, although specific mechanisms have yet to be identified. Possibilities exist for improving Douglas-fir regeneration by controlling salal and enhancing nutrient cycling through site preparation. This summary describes a study that tested the effectiveness of several scarification treatments, as well as the herbicide control of salal, on Douglas-fir regeneration performance on dry, nutrient-poor to medium ecosystems.

METHODS

The study (FRDA 2.17) was established at two locations on Vancouver Island. Both sites represent Douglas-fir-Western hemlock-Salal ecosystems in the CWHa1 biogeoclimatic variant of the Coastal Western Hemlock (CWH) zone. The Lens Lake location, north of Campbell River, represents a slightly dry, nutrient-poor (3/B) site on a gentle NW-facing slope at 250 m elevation. The Cameron location, east of Port Alberni, is a moderately dry, nutrient-medium site (2/C) on a moderate SSW-facing slope at 640 m elevation. Logging had taken place in both areas in 1985, with the study established in 1986 and planted in 1987.

The treatments tested at both locations included control (C), spot scalp (SS), spot scalp with legumes and fertilizer (SSLF), spot mix (SM), and foliar application of Garlon 4® (trichlopyr ester) in diesel (G). At the Lens Lake location, an operational blade scalping project was incorporated into the study, featuring blade scalp (BS), blade scalp with legumes and fertilizer (BSLF), and mixed berm (MB - trees planted along berm edges) treatments. All spot scarification treatments were done manually for treatment uniformity. The legumes included a mixture of clovers and birdsfoot trefoil, applied with a small amount of starter fertilizer. In the spring of 1988, S-urea (12 g N/tree) was applied in dibble holes 15 cm from the seedlings. The objective of the Garlon® treatment was to create a salal-free area without disturbing the forest floor. It was initially applied as a dormant season treatment in 1986, with a follow-up spot application in August 1987 to reduce residual leaf area.

RESULTS

Height Growth

Height growth of Douglas-fir over three growing seasons at the Lens Lake location did not differ among C, SS, SM, BS, and MB treatments. Fertilizer provided a dramatic response, however, with 50% greater 3rd-year height measured in SSLF and BSLF treatments relative to controls (legumes failed to establish successfully in both locations). Trees in the G treatment initially suffered some top dieback after the spot spray, likely because of drift; they have, however, subsequently shown slightly better height growth relative to other unfertilized treatments. At the Cameron site, trees also responded dramatically to

fertilizer, with the SSLF treatment showing a 60% improvement in 3rd-year height compared to controls. Unlike the Lens location, however, trees in the G treatment paralleled fertilized trees in height performance, showing the same 60% improvement in 3rd-year height. Other treatments (SS, SM) showed no growth advantage over controls.

Mortality and Seedling Condition

Mortality at the Lens site was low, with only the G treatment showing higher mortality (8%), which can be attributed to herbicide drift damage. Similar damage in the G treatment occurred at Cameron, though overall mortality was higher, reflecting greater moisture stress on this site.

At Lens Lake, the frequency of chlorotic trees was high, reflecting poor soil nutrition. While most treatments showed some improvement after 3 years, the fertilized trees showed increasing chlorosis, indicating the fertilizer effect is diminishing. Trees in the G treatment at Lens currently have the lowest incidence of chlorosis (48%). The frequency of chlorotic trees was much lower at Cameron because of its better soil nutrition. As at Lens, fertilized trees looked better initially, but are now showing signs that the fertilizer effect is declining. Trees in the G treatment have the lowest incidence of chlorosis (8%) and look substantially better than those at Lens. Because of improved foliar nutrient content reflected in green foliage, deer browse and lammas growth occurred more frequently in fertilizer and G treatments at both locations.

DISCUSSION

Removing salal leaf area with Garlon® while retaining an intact forest floor substantially reduces soil water losses relative to untreated controls or treatments which scalp or disturb the forest floor. This had a pronounced effect at the Cameron site which was very limiting in soil moisture, but reasonably good in soil nutrition. At the Lens site, soil water is not so limiting, while soil nutrients are more limiting, relative to Cameron. As a result, the G treatment produced a positive, but less consistent or dramatic response.

SUMMARY

1. Salal competes primarily for water on these sites.
2. Spot scarification does not buy you much.
3. Fertilizer provides good initial response.
4. Reducing salal leaf area while leaving the forest floor intact shows most promise.
5. Differences in site properties can have a big impact on treatment response.

POSTERS

Competition and Vegetation Dynamics

Problems with the Development and Application of Competition Indices in Complex, Multispecies Communities

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Competition indices are currently being developed for use as tools in the assessment of vegetation problems and the evaluation of treatment alternatives in forest management. Most of these indices are derived from the relationship between the growth and survival of a target species, and a simple measure of the number, size, or proximity of its neighbours. Competition for limited resources is assumed to be the major underlying process structuring this relationship. Although there are situations in which indices may be useful (e.g., young, even-aged, single growth form stands), there are a number of reasons to be critical of their potential for widespread application in complex, multispecies communities. Some of these reasons are presented here using examples from a neighbourhood study which formed part of a larger research project on factors affecting the performance of Engelmann spruce seedlings on subalpine cutovers.

THE EXPERIMENT

An experiment was set up in 1987 to study the impact of two major subalpine vegetation types on the early growth and survival of planted Engelmann spruce. The research was carried out on two adjacent sites logged to a diameter limit of 8 inches in the winter of 1983 and classified as understocked in 1986. The sites were located at 1550 m in the Engelmann Spruce-Subalpine Fir zone (ESSFwc2 subzone) of south-central British Columbia.

On both sites, seedlings of a 2-0 cold-stored and a 2-0 hot-planted plug stock were planted in plots located in dense shrubs and dense herbs. Vegetation in the herb plots was dominated by Sitka valerian (*Valeriana sitchensis*), western meadowrue (*Thalictrum occidentale*), and oak fern (*Gymnocarpium dryopteris*). Vegetation in the shrub plots was dominated by false azalea (*Menziesia ferruginea*), white-flowered rhododendron (*Rhododendron albiflorum*),and huckleberry (*Vaccinium membranaceum*). All plots had both shrubs and herbs. Vegetation from 50% of the plots of each vegetation type was removed before planting.

RESULTS

The data from a neighbourhood study on a randomly selected subsample of seedlings in control plots were used to examine the relationship between seedling growth and associated vegetation. A neighbourhood was defined by the height and % cover of each species within a radius of 25 cm of a target seedling. Two measures of the neighbourhood were derived from the data set. One was a sum of the % cover of each species within a neighbourhood plot. The other was a sum of height X % cover of each species within a plot.

A comparison of the growth of seedlings three seasons after planting showed large differences between control and treated plots for both shrub dominated and herb dominated vegetation types. The stem volume (d^2ht) of seedlings under competition ranged from 9 to 44% of that of competition-free seedlings (Figure 1). There were also, however, large differences in the responses of seedlings between sites and stock types. The results suggested a greater competitive response by the hot-planted stock

relative to the cold-stored stock and a greater competitive response on site 1 than on site 2. Snow duration was longer, soil temperature was lower, and soil moisture was higher on site 2.

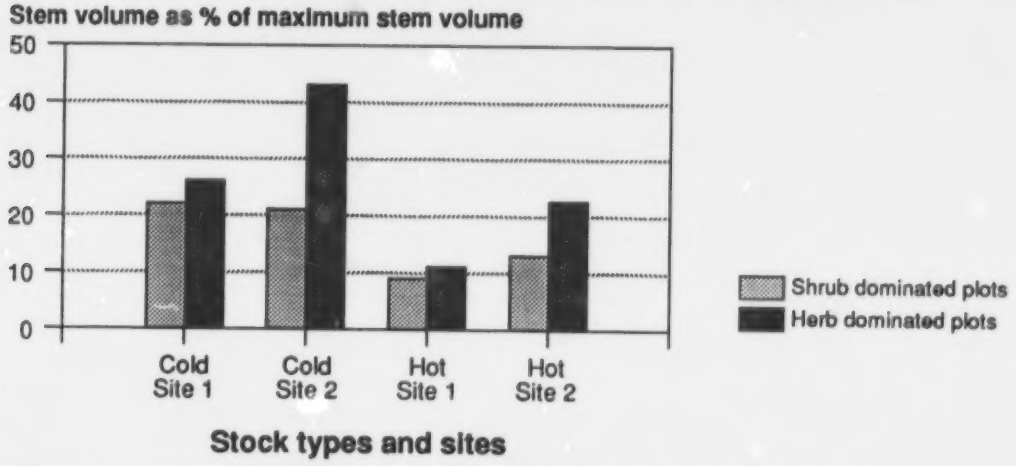


FIGURE 1. Reduction in seedling stem volume in two competitive neighbourhoods.

There was no relationship between the growth of the cold-stored stock and either of the two neighbourhood measures. However, the growth of hot-planted stock seedlings was strongly related to both measures on site 2. There was a significant negative linear correlation between the relative growth rate (RGR) of hot-planted stock seedlings and shrub cover across all plots (Figure 2). If herb plots were removed from the data set, the relationship remained significant, but if shrub plots were removed, leaving only herb plots, the results were nonsignificant (despite shrub covers of up to 70% in herb plots). Similarly, there was a positive linear correlation between the RGR of seedlings and herb cover (Figure 3). This relationship held for herb plots alone, but not for shrub plots alone (where herb covers were up to 50%).

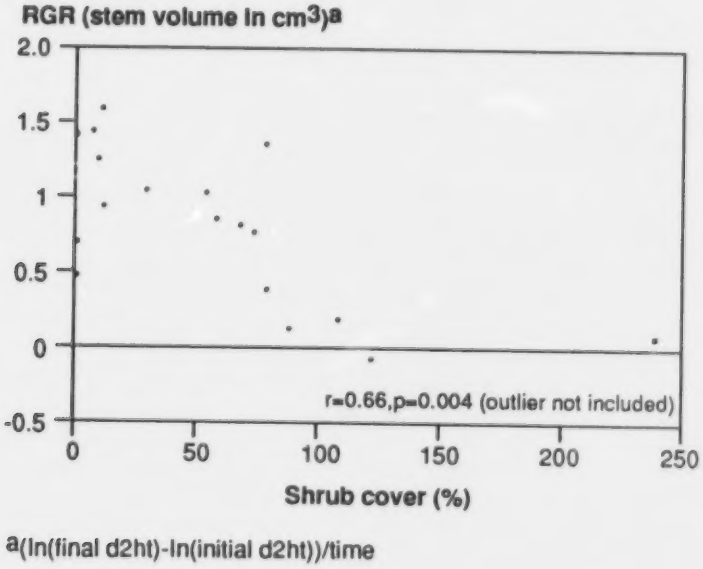
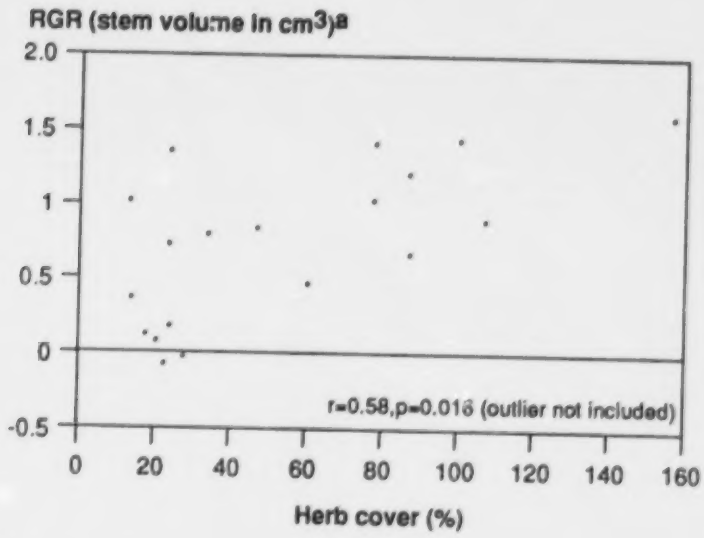


FIGURE 2. Hot-planted Engelmann spruce seedling growth rate vs shrub cover on site 2.



a(ln(final d2ht)-ln(initial d2ht))/time

FIGURE 3. Hot-planted Engelmann spruce seedling growth rates vs herb cover on site 2.

DISCUSSION

These results suggest that competitive effects are strong only at high densities of neighbours (such as were selected for in this study). Similarly, many studies on competition indices have found that target species respond to reduced competition only after the density of competitors has been reduced to relatively low levels. Over the wide range of intermediate densities at which most natural populations occur, however, competition may not be a major process underlying plant growth. Density relationships in this intermediate region may be only vaguely related to competition, and more strongly related to abiotic conditions and resource quality. Only at very high or low densities can density relationships be expected to be well defined. The possibility of a broad region of density-vagueness calls into question the relationships on which many competition indices are based.

The concept of a competition threshold is currently viewed as having much potential for the prediction and assessment of vegetation problems. No evidence of a competition threshold emerged from the results of this neighbourhood study, but the identification of a threshold typically requires a very large number of data points because the response of individual trees is always highly variable.

Not only can thresholds be difficult to locate, but their locations will shift over time with the size or physiological state of the target species, or the relative importance of biotic and abiotic factors unrelated to competition. The low, albeit significant, r^2 on which competition indices are frequently based, suggests that there is important information on the relationship between a crop species and its neighbourhood that is masked by many indices. It seems intuitive, for example, that the effects of neighbours on a target species will differ depending on the resources available to the target species, as well as on the utilization capabilities and resource requirements of different neighbourhood species. The results from this study suggest that the competitive responses of Engelmann spruce seedlings are influenced by site factors, neighbourhood composition, and the characteristics of the seedlings at the time of planting. It is suggested that an approach employing dynamic simulation models responsive to changing conditions over time and space may yield greater potential for the development of management tools for the assessment and prediction of vegetation problems.

Effects of Light and Soil Water Limitations on Douglas-fir and Red Alder Carbon Allocation and Physiological Patterns

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INTRODUCTION AND OBJECTIVES

The objectives of this study are to elucidate the morphological, allocable and physiological mechanisms by which Douglas-fir and red alder adapt to environmental limitations. Information on the ecophysiological responses of field-grown Douglas-fir and red alder saplings to limitations in light and soil water availability is scarce. Such information is necessary if a mechanistic approach is taken to link resource availability with growth. Manipulation of vegetation ultimately results in the modification of site resource availability, which in turn affects tree physiology and growth. Knowledge of probable growth mechanisms is intended to provide forest managers with the conceptual means to maximize site resource utilization and tree development.

METHODS

Individual 1-year-old transplants of Douglas-fir and red alder were studied for 3 years on an experimental research field site near Corvallis, Oregon. The trees were subjected to treatments consisting of two levels of light (full sunlight and 13% of normal) and soil moisture (irrigated and non-irrigated) in all four possible combinations, to simulate a probable functional environment created through plant competition in the Oregon coast range. Trees were planted in polyethylene-lined holes 1 m deep by 0.5 m wide, filled with silty clay loam. The lining facilitated the regulation of soil water and expedited whole tree harvesting. Light level was controlled with tepee-shaped shade tents covered with shade cloth. Soil moisture was maintained by drip irrigation. Morphological and physiological parameters of the trees were measured monthly during the growing season to determine sapling responses to differences in light and soil availability. Trees were harvested at the end of the study to assess strategies in biomass allocation patterns.

RESULTS AND DISCUSSION

Biomass production and stem growth in both red alder and Douglas-fir were more sensitive to light than to the soil moisture conditions established in this study. Red alder at age 4 accumulated 9 times more biomass than did Douglas-fir (Table 1). Douglas-fir allocated a higher proportion of biomass to roots, suggesting a drought avoidance strategy. Red alder exhibited a drought tolerance strategy characterized by higher allocation to shoots and leaf abscission when subjected to severe drought. Trees of both species allocated less biomass to roots when grown under shaded and irrigated condition (Figure 1).

TABLE 1. Summary effects of light and water limitations on Douglas-fir and red alder morphology and biomass

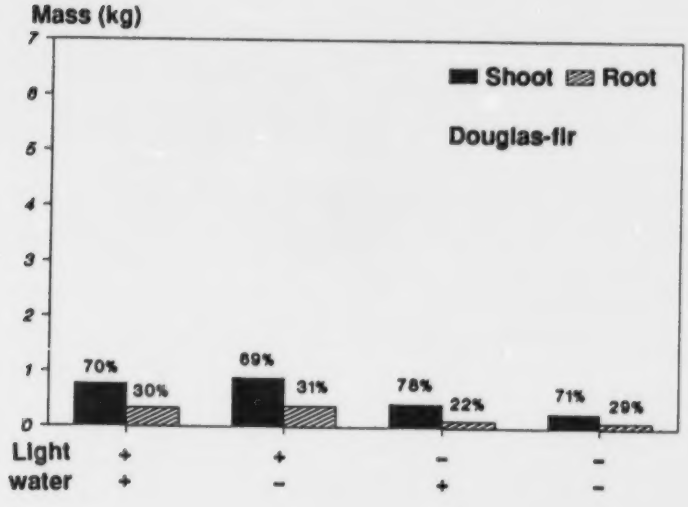
Light	Water	Stem diameter (cm)		Tree weight (g)	
		Douglas-fir	Red alder	Douglas-fir	Red alder
+	+	4.6 ± 0.2	9.8 ± 0.5	1101 ± 81	9643 ± 678
+	-	4.4 ± 0.2	7.1 ± 0.5	1267 ± 82	4836 ± 419
-	+	3.1 ± 0.2	5.5 ± 0.5	554 ± 87	2143 ± 291
-	-	2.6 ± 0.2	4.6 ± 0.5	387 ± 82	1202 ± 285

Red alder, despite its higher photosynthetic rate and water use efficiency, had a lower efficiency for production of new biomass per unit of leaf area (Figure 2). A substantially higher leaf area and the rapid accumulation of non-photosynthetic tissue during juvenile development may result in higher maintenance costs as the trees age and begin to close canopy. This may partially explain why red alder stands stagnate and self-thin at a relatively young stand age.

Watered Douglas-fir and red alder trees depleted 3-4 times more soil moisture than non-watered trees. Despite alder's greater mass and leaf area, alder extracted only 2 times more soil moisture than Douglas-fir, again suggesting a higher water use efficiency (Table 2). Irrigating to field capacity on a weekly basis improved the growth of shade-stressed Douglas-fir trees, but did not improve the growth of Douglas-fir trees in unshaded conditions. This suggests that Douglas-fir trees in soils of high water holding capacity may benefit more from manipulations that increase light availability. Silvicultural treatments that alter the availability of light and soil water are likely to have a greater impact on the growth of red alder than Douglas-fir. The response patterns of Douglas-fir and red alder reported in this study suggest that managers may substantially influence sapling vigour and allocation through silvicultural manipulations that modify the availability of light and soil water.

TABLE 2. Soil moisture depleted by 4-year-old Douglas-fir and red alder from May to October

	Soil depth (cm)	Watered		Not watered	
		Tree use (cm/m)	Tree use + evaporation (cm/m)	Tree use (cm/m)	Tree use + evaporation (cm/m)
Douglas-fir					
	0-50	7.63	9.93	2.68	5.18
	50-100	8.25	10.73	2.05	5.00
Red alder					
	0-50	13.65	15.83	4.78	6.45
	50-100	14.60	17.08	3.03	5.98



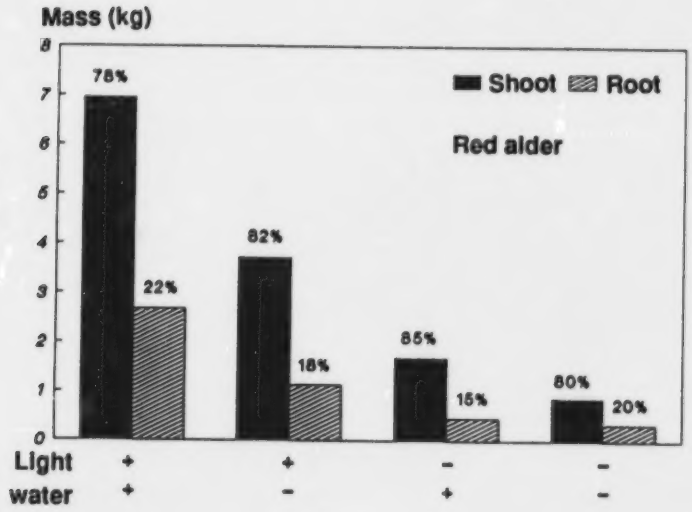


FIGURE 1. Shoot and root allocation of 4-year-old Douglas-fir and red alder in response to light and water availability.

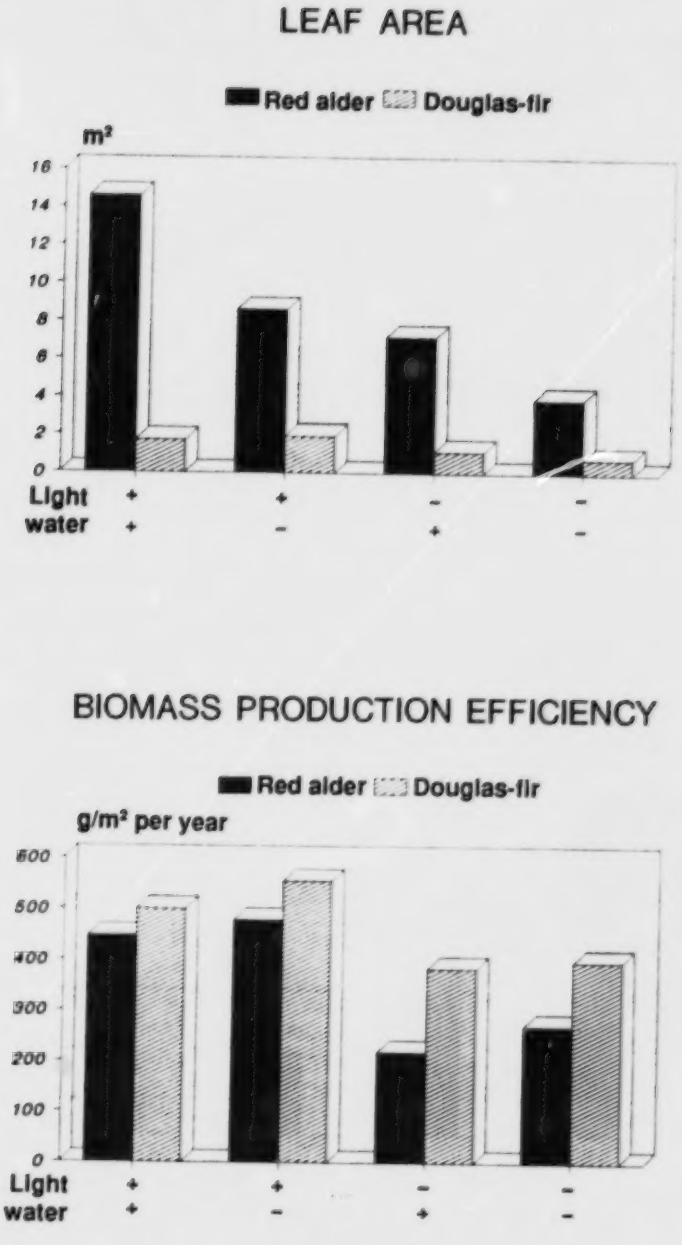


FIGURE 2. Leaf area and biomass production efficiency for 4-year-old Douglas-fir and red alder in response to light and water availability.

Carbon Allocation and Seasonal Photosynthetic Response of Western Redcedar Seedlings Under-planted within Red Alder and Birch Stands

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INTRODUCTION

Competition for light between evergreen and deciduous competitors has traditionally been assessed during the mid-growing season when deciduous plants are fully foliated. This method fails to account for photosynthesis by evergreen species during the period when deciduous species are leafless during October through November and March through April.

Shade-tolerant evergreen conifer species such as *Thuja plicata* (western redcedar) are well adapted to grow (albeit slowly) under extremely low light levels (<5% full sunlight). This paper reports on the preliminary results of an ongoing 48-month study of carbon allocation, net photosynthesis, and light attenuation of western redcedar seedlings planted within birch and red alder stands in southwestern British Columbia (Malcolm Knapp Research Forest).

The main objectives of this study are:

1. to quantify seasonal patterns of photosynthesis by western redcedar seedlings under-planted in deciduous tree stands;
2. to quantify and compare seasonal changes in light attenuation within birch and red alder stands;
3. to quantify carbon allocation (above- and below-ground) of western redcedar seedlings growing under low light conditions in the field.

METHODS

This project was established in April 1989 at the Malcolm Knapp Research Forest, Haney, B.C. One hundred western redcedar seedlings (1-year-old plugs) were planted within each of two deciduous stands (birch and red alder). Light levels under both these stands are 2-5% of full sunlight during mid-summer. One hundred conifer seedlings were also planted into open plots adjacent to both stands (full sunlight controls).

Diurnal and seasonal measurements of photosynthetic and stomatal conductance are being collected and diameter, height growth, and carbon allocation (foliage, stem, and roots) are being measured. Rates of photosynthesis and stomatal conductance are also being measured on nine sample seedlings per treatment per sampling time using a portable closed CO_2 gas analyzer (LI COR 6200 Portable Photosynthesis System, Lincoln, Nebraska). Light attenuation is determined with the use of point light sensors and line quantum sensors.

In early November 1989, 15 western redcedar seedlings per treatment were harvested (shoot and root) for complete growth analysis. All seedlings were partitioned into non-photosynthetic shoot, foliage, and roots. All components were oven-dried for 48 hours at 70°C and weighed.

RESULTS

Net Photosynthesis and Light Attenuation

Mid-summer photosynthetic rates of western redcedar seedlings growing within the birch and red alder stands were just above the compensation point for most of the summer (Figure 1). This was related to the low light levels recorded under these stands during the summer when the canopies were fully foliated. However, even at these low levels net photosynthesis was still occurring and resulted in a net carbon gain. In comparison, net photosynthetic rates of open-grown seedlings were 4 times greater than the rates in under-planted seedlings, indicating that at light levels less than 5% of full sunlight shaded western redcedar seedlings are only photosynthesizing at 25% of maximum (Figure 2).

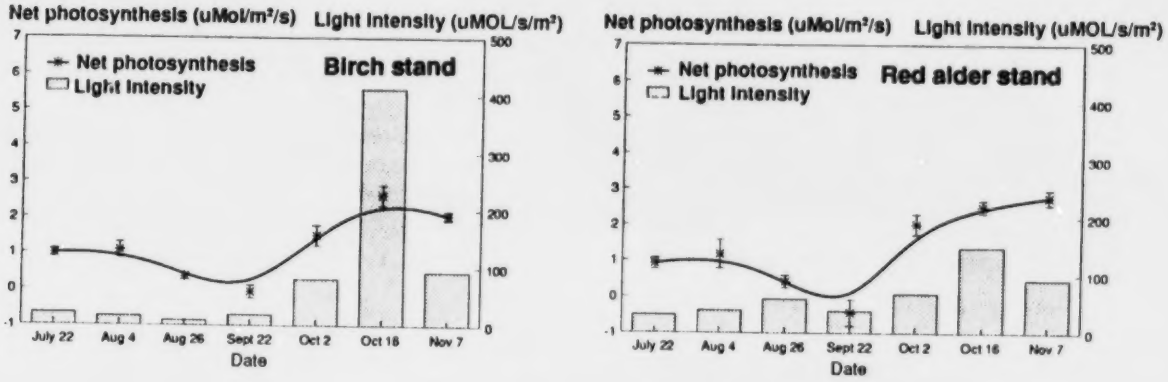

FIGURE 1. Light intensity (PAR) and net photosynthetic response of western redcedar seedlings under-planted within a red alder and birch stand. Bars around each point represent 1 standard error. The Nov. 7 measurements were made under cloudy conditions.

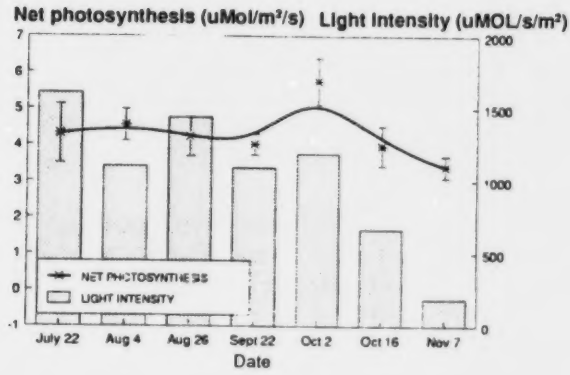

FIGURE 2. Net photosynthetic response of planted western redcedar seedlings growing in the open (no light competition). Bars around each point represent 1 standard error. The Oct. 16 and Nov. 7 measurements were made under cloudy conditions.

The start of leaf fall by both birch and alder in late September resulted in an increase in the amount of light reaching the western redcedar seedlings. By October 2, light intensity under both the birch and alder stands had increased approximately 300 and 75% respectively as a result of leaf death and leaf fall. A rapid increase in net photosynthesis by western redcedar seedlings coincided with increased light intensity. By October 16, net photosynthetic rates were approximately 150% greater than mid-summer rates under both birch and alder stands.

Carbon Allocation

After 6 months in the field, western redcedar seedlings grown under full sunlight (no light competition) showed significantly greater biomass increment than seedlings grown under low light conditions. Open-grown seedlings showed a 29 and 31% increase in total seedling biomass over the birch and alder under-planted seedlings respectively (Table 1).

TABLE 1. Biomass (g) allocation, by component, of western redcedar seedlings grown for 6 months under a birch (n=15) and red alder (n=15) stand and in the open (n=15). Pre-planting biomass determination was made on 40 randomly chosen seedlings. Numbers within brackets represent + or - 1 standard error. Means within each column having the same letter are not significantly different at p=0.05.

Treatment	Weight (g)				
	Stem	Foliage	Root	Shoot	Root/Shoot
Pre-plant	1.1(0.05)	1.7(0.08)	1.4(0.01)	2.8(0.12)	0.65(0.04)
Birch	^{a}1.5(0.08)	^{a}2.2(0.13)	^{a}1.6(0.09)	^{a}3.7(0.19)	^{ab}0.43(0.03)
Alder	^{a}1.7(0.13)	^{a}2.3(0.17)	^{a}1.5(0.10)	^{a}4.0(0.29)	^{a}0.39(0.02)
Open	^{b}2.2(0.15)	^{b}3.1(0.30)	^{b}2.5(0.23)	^{b}5.2(0.44)	^{b}0.49(0.02)

DISCUSSION

It is evident from these preliminary results that western redcedar seedlings can photosynthesize well into the late fall. In addition, seedlings growing in the understory of deciduous stands respond rapidly (physiologically) to an increase in light availability in the autumn. The extent of CO_2 uptake of western redcedar during the period from October to April when the competing deciduous species are leafless will not be fully quantified until a complete data set from one 12-month period is collected and analyzed.

Implications For Vegetation Management

The use of shade-tolerant crop species such as western redcedar on brush-prone sites in southwestern British Columbia may be an appropriate choice by managers. The ability of this species to grow under low light conditions makes it an attractive choice, especially in areas where herbicide use is prohibited.

We would like to thank the staff at the Malcolm Knapp Research Forest for their assistance in this project.

Understanding Salal as a Competitor

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INTRODUCTION

Salal (*Gaultheria shallon* Pursh) is a very common ericaceous shrub which thrives on poor to medium sites in many low and mid-elevational coastal forests in British Columbia. It is thought to compete with crop trees in all phases of stand development, and impede the establishment and growth of commercial tree species in both naturally and artificially regenerated stands. This summary reviews the main factors to consider to understand salal as a competitor. A pamphlet for field use on this subject will be available (FRDA Project 2.32).

SALAL GROWTH HABITS

Following clearcutting, salal quickly reinvades cutovers in the Coastal Western Hemlock (CWH) Zone by resprouting from rhizomes present prior to logging. Regrowth of roots is especially rapid and salal can fully occupy the below-ground environment on CWHb1 sites within 8 years (Messier *et al.* 1988). It has been estimated that 30-45% of the available nitrogen is removed from some CWHb1 sites by salal annually and accumulated in its biomass (Messier and Kimmins 1989). This increase in salal biomass and consequent immobilization of nutrients will eventually plateau and then decline as the tree canopy develops. As the tree canopy closes, salal allocates proportionally more biomass to its shoots than its roots (Figure 1). At tree covers greater than 80%, below-canopy light intensities become insufficient to support salal (Messier *et al.* 1989).

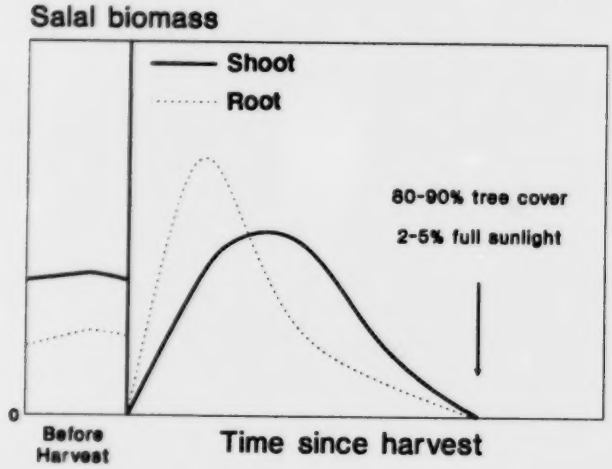

FIGURE 1. Hypothetical relationship between the shoot and root biomass of salal under developing stands. The arrow indicates the stand cover and light conditions at which salal is shaded out.

SALAL ANTAGONISTIC INTERACTIONS

Salal can compete with trees for water and nutrients. It may also alter soil characteristics and/or release compounds that negatively affect the normal growth of crop trees (i.e. allelopathy). In the Coastal Douglas-fir (CDF) Zone, Price *et al.* (1986) showed that the salal understory competed with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) for water. This detrimental impact is more likely to occur in young open plantations when the shoot and root biomass of salal is high (see Figure 1). On moister sites, salal may compete for nutrients with Sitka spruce (*Picea sitchensis* Bong. Carr.) and western hemlock (*Tsuga heterophylla* Raf. Sarg.), and to a lesser extent with western redcedar (*Thuja plicata* Donn) (Figure 2). Extensive field and pot experiments failed to find any evidence for a direct allelopathic contribution to the growth reduction of Sitka spruce (Messier and Kimmins 1989; M. McDonald, pers. comm.), western hemlock, and western redcedar (Messier, in prep.) growing with salal. However, salal may reduce the fertility of the site by producing litter that either slows decomposition of the forest floor or simply decomposes slowly by itself. Based on our results to date, the nutritional stress in Sitka spruce plantations near Port McNeill is thought to be caused by a combination of (1) salal competition for nutrients and their subsequent immobilization in salal biomass, and (2) declining site fertility caused by the termination of the flush of nutrients (i.e. the "assart effect") that occurs following clearcutting and slashburning (Messier and Kimmins 1989). Although it can be serious, the early competition by salal will not persist under good stand growing conditions, as the biomass and nutrient accumulation by salal comes to a stop and then declines (Figure 1) as the tree canopy closes. Over a rotation length period the impact of salal may be minor, as suggested in the study by Klinka *et al.* (1989).

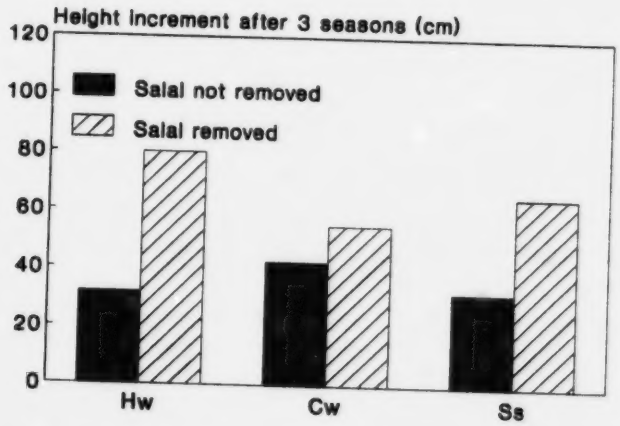

FIGURE 2. Effects of salal removal on seedling height growth for the first 3 years after planting (Hw: western hemlock; Cw: western redcedar; Ss: Sitka spruce).

SUMMARY

On salal-dominated sites the following points should be considered:

1. Following logging, salal re-establishes itself rapidly from rhizomes and the roots can fully occupy the below-ground environment quickly.
2. Salal cover is a useful index of competition during the regeneration period, but not after tree canopy closure.
3. Sitka spruce and western hemlock appear to be more sensitive to salal competition than do western redcedar and Douglas-fir.

4. On moist sites, the impact of salal should decline sharply following tree crown closure. On dry sites, the impact may last longer and one should be cautious with thinning practices.

5. Dense and vigorous plantations of the most suitable species will eventually shade out salal, and the rotation length impact of salal may be minor.

6. Salal is most abundant on nutrient-poor to -medium sites where slow tree growth is expected. Such slow growth may, therefore, reflect the site conditions as much as or more than the presence of salal.

7. The growth "check" in Sitka spruce plantations near Port McNeill relates to the low nutrient availability on these sites and the high nutrient requirement of this species (Miller and Miller 1987).

REFERENCES

Klinka, K., R.E. Carter, M.C. Feller, and Q. Wang. 1989. Relations between site index, salal, plant communities, and sites in Coastal Douglas-fir ecosystems. Northwest Sci., 63:19-27.

Messier, C., T.W. Honer, and J.P. Kimmins. [1989]. Photosynthetic photon flux density, red:far-red ratio, and minimum light requirement for survival of *Gaultheria shallon* in western redcedar/western hemlock stands in coastal British Columbia. (Submitted to Can. J. For. Res.). In press.

Messier, C. and J.P. Kimmins. [1989]. Nutritional stress in *Picea sitchensis* plantations in coastal British Columbia: the effects of *Gaultheria shallon* and declining site fertility. (Submitted to Water, Air and Soil Pollution). In press.

Messier, C., R. Oran, and J.P. Kimmins. 1988. Root distribution and biomass of competing vegetation on two recently burned sites in the CWHb subzone. *In* Vegetation Competition Responses: Proc. 3rd Annual Vegetation Management Workshop, Victoria, B.C. FRDA Rep. 026.

Miller, H.G. and J.D. Miller. 1987. Nutritional requirements of Sitka spruce. *In* Sitka spruce. Proc. of the Royal Society of Edinburgh. Section B (Biological Sciences). D.M. Henderson and R. Faulkner (editors), pp. 75-83.

Price, D.T., T.A. Black, and F.M. Kelliher. 1986. Effects of salal understory removal on photosynthetic rate and stomatal conductance of young Douglas-fir trees. Can. J. For. Res. 16:90-97.

Vogt, K.A., D.J. Vogt, E.E. Moore, B.A. Fatuga, M.R. Redlin, and R.L. Edmonds. 1987. Conifer and angiosperm fine-root biomass in relation to stand age and site productivity in Douglas-fir forests. J. Ecol. 75:857-870.

Aspen Competition and Lodgepole Pine Growth in Mixed Regeneration in Western Alberta

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INTRODUCTION

Regeneration surveys show that there is an increase in aspen density and a gradual shift to mixedwood regeneration after harvest of pine and pine/aspen cover types. Aspen regenerates in these areas by both suckering and seeding (Navratil *et al.* 1989).

Foresters have little information to use in estimating 1) the effects of aspen competition on the growth of lodgepole pine (*Pinus contorta* Dougl.), 2) the need and timing of conifer-release treatments, 3) the development of mixed regeneration, and 4) long-term changes in softwood yield.

Forestry Canada, Northern Forestry Centre, Edmonton, has initiated a study to develop a silvicultural decision tool for predicting aspen regeneration and competition on mixedwood sites, and ranking of areas for hardwood or softwood production and silvicultural treatments.

This paper describes the component of the study that has the objective of estimating the effects of aspen on growth of 4-to 12-year-old pine in mixed stands.

METHODOLOGY

The methodology was based on a tree-centred approach and the concepts of interspecific competition indices developed by Brand (1986), Wagner *et al.* (1989), and DeLong[1]. A system of intensive and extensive sampling plots was designed to measure 36 variables of shrub and tree competitors and crop tree characteristics such as crown size, total height, height increments, age, basal diameter, and radial increments.

RESULTS

In the first analysis (1988 data), competition variables and known competition indices were screened and the "best" and most operationally feasible predictors of pine growth were selected. Visually estimated percent cover of aspen alone, or as a component of competition indices, reflected all the growth responses of pine to competition, particularly for radial growth variables. We developed growth/competition relationships and reviewed these for biological soundness. Growth models (modified Chapman-Richard function) were developed separately for aspen suckers and aspen seedlings. The trends of relative crop tree size (relative to a pine free of competition) suggested that 10-20% aspen cover

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[1] Personal communication from C. DeLong of B.C. Ministry of Forests, Prince George, B.C., 1988.

had a positive effect on lodgepole pine seedling growth. Higher levels of aspen cover had a negative effect on lodgepole pine growth.

A set of regression equations was used to quantify the changes in pine and aspen growth at different competition and density levels. Growth of pine was influenced primarily by age, cover of crop species, cover of aspen, and aspen density. The program is designed to help foresters estimate the severity of competition and growth losses. Work is in progress to model and incorporate the dynamics of competition by simulating the growth (crown cover and height) of competitors and crop trees and subsequently stand development.

LITERATURE CITED

Brand, D. 1986. A competition index for predicting the vigour of planted Douglas-fir in southwestern British Columbia. Can. J. For. Res. 16:23-29.

Navratil, S., I.E. Bella, and E.B. Peterson. 1989. Silviculture and management of aspen in Canada: the western Canada scene. A paper presented at the Aspen Symp. '89, July 25-27, 1989, Duluth, Minn. In press.

Wagner, R.G., and S.R. Radosevich. 1987. Interspecific competition indices for vegetation management decisions in young Douglas-fir stands on the Siuslaw National Forest: Rep. No. 1. 96 p.

Balancing the Positive and Negative Effects of Non-Crop Plants on Conifers: Pinegrass, Fireweed, Sitka Alder and Paper Birch – Friend and Foe

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Non-crop plants are usually managed to reduce their negative effects on the survival and growth of conifers. Non-crop plants can compete for resources, alter environmental conditions, or cause physical damage. Under some conditions, however, non-crop plants should be managed to enhance their positive characteristics, which include nutrient cycling, nitrogen fixation, and frost protection. Regardless of the management objectives, successful regeneration requires a knowledge of the growth, reproductive, and interactive characteristics of non-crop plants. We present some results from four FRDA projects established in the southern interior of British Columbia. Each project investigates interactions among conifers and one of the non-crop plant species: pinegrass (*Calamagrostis rubescens*), fireweed (*Epilobium angustifolium*), sitka alder (*Alnus viridis* ssp. *sinuata*), and paper birch (*Betula papyrifera*).

GROWTH AND REPRODUCTIVE CHARACTERISTICS

Pinegrass is common in the Interior Douglas-fir (IDF) zone and also occurs in the Ponderosa Pine (PP), Interior Cedar Hemlock (ICH), Sub-Boreal Spruce (SBS) and Engelmann Spruce-Subalpine Fir (ESSF) zones. Pinegrass produces seed infrequently and flowers only in forest openings during moist summers. It reproduces vegetatively from creeping rhizomes. Pinegrass grows quickly early in the spring and completes its growth when moisture is most available.

Fireweed occurs in all zones. It produces thousands of wind-dispersed seed (20 000-80 000/plant). Once established on a site, it reproduces vegetatively by rhizomes. Fireweed grows rapidly early in the spring and reaches its full height (up to 3 m) by mid-July.

Sitka alder is found in all zones except the PP and Bunchgrass (BG). It produces large numbers of seed that are dispersed over long distances. The growth rate of seedlings ranges from 10 to 30 cm per year. Sitka alder also reproduces vegetatively by sprouting from the stump. Sprouting ability varies according to moisture availability and ranges from 5 to 80 cm/year.

Paper birch is restricted to the ICH and moist subzones of the IDF. It produces large numbers of light-winged seed, with heavy seed crops every 2 years. Juvenile growth rates of seedlings range from 10 to 40 cm/year, and of basal sprouts, up to 2 m/year.

INTERACTIONS WITH CONIFERS

Competition for Water, Light, and Nutrients

Growth depends on a seedling's ability to extract resources, primarily moisture, light, and nutrients, from the environment. When resources are in short supply, seedlings must compete for them with neighbouring non-crop plants.

Water

Plants have different adaptations for coping with drought. Pinegrass exploits moisture at the expense of conifer seedlings because of rapid, early growth and high water use. Pinegrass can transpire and photosynthesize at high rates, even after moisture conditions have caused tree seedlings to close their stomata (Figure 1).

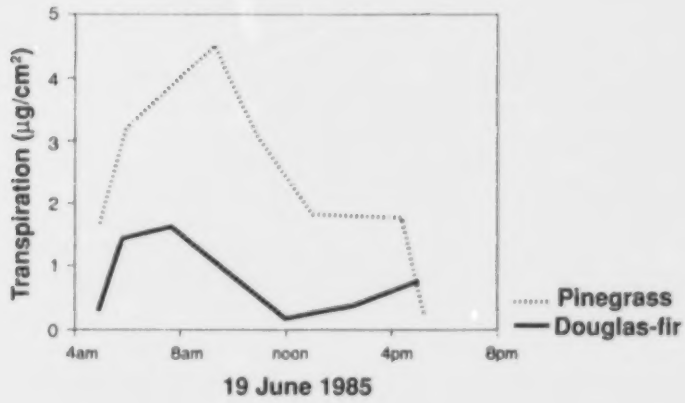

FIGURE 1. Comparison of pinegrass and Douglas-fir seedling transpiration rates. Pinegrass loses at least twice as much water per unit of foliage as Douglas-fir.

Light

Shade-tolerant species such as spruce can withstand lower light intensities than can shade-intolerant species such as lodgepole pine. Dense canopies of non-crop vegetation are capable of intercepting over 95% of full sunlight. Under such low light intensities, shade-intolerant species can quickly become weak and spindly.

Nutrients

Nutrient competition is likely to be most severe on sites where nutrients are in limited supply. Conversely, non-crop plants may interact beneficially with conifers by taking up, storing, and recycling nutrients that might otherwise be lost. Some non-crop species can improve soil conditions by fixing nitrogen. Sitka alder has been shown to fix nitrogen at rates of up to 62 kg/ha per year.

Alteration of Environmental Conditions

Non-crop plants have the ability to alter environmental conditions, such as temperature, in a manner which may be favourable or unfavourable for seedling growth.

Soil temperature

Non-crop plant cover reduces heat transfer into the soil during the day, resulting in decreased soil temperatures (Figure 2). The lowered soil temperatures early in the spring may impede conifer root growth.

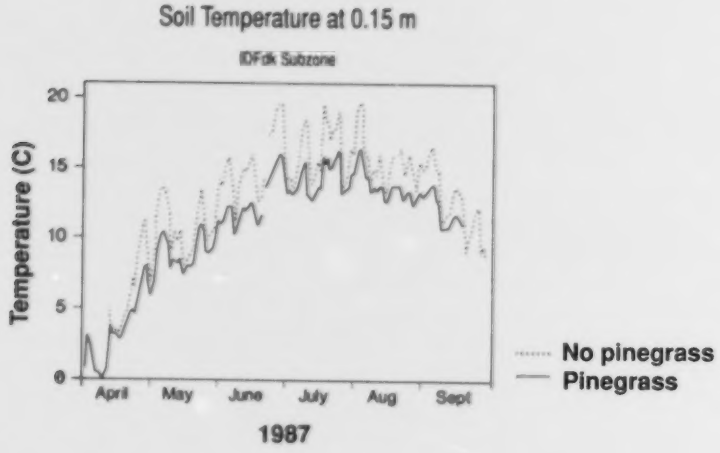

FIGURE 2. A comparison of soil temperatures over the course of the growing season between pinegrass-covered and bare ground in the IDFdk subzone.

Frost

Tall, dense canopies of Sitka alder, paper birch, or fireweed often provide protection from radiation frost. They reduce the seedling's view of the sky and trap warm air.

Physical Damage

Non-crop plants can physically damage neighbouring seedlings. Dense canopies of fireweed may press and bend seedlings when they senesce in the fall. Heavy snow packs will further press and distort growth. Sitka alder and paper birch stems may cause damage to saplings by whipping the stems, branches, and leaders in the wind.

HOW MANY NON-CROP NEIGHBOURS ARE TOO MANY?

Competition Thresholds

A competition threshold is the abundance of non-crop vegetation at which competition begins and seedling performance rapidly declines. Management practices should aim to decrease non-crop abundance below critical thresholds. Quantifying competition thresholds in forest plantations is difficult, however, because of the confounding influence of factors other than vegetative competition. Furthermore, competition thresholds may vary according to conifer and non-crop species, their ages, and the environment.

Survival Versus Growth Thresholds

Thresholds for survival and growth are different. Generally, seedlings can survive under high levels of environmental stress imposed by competing vegetation. Growth is much more affected by stress, and already is considerably reduced when mortality occurs. Sometimes a threshold level of interference does

not appear to exist. On a pinegrass-dominated site in the IDF zone, survival was limited by a complex of factors including drought, frost, rodent damage, and competition.

Environmental Effects on Growth Thresholds

Thresholds for growth vary considerably with environmental conditions. In Sitka alder-dominated communities in the MS zone, lodgepole pine grows well up to certain densities of Sitka alder. On dry, cool, nutrient-poor sites, the density of Sitka alder that can be retained without considerable decreases in growth is greater than on moist, warm, more nutrient-rich sites (Figure 3). In paper birch-dominated communities in the ICH zone, Douglas-fir performs best when growing in the open. The competitive ability of birch, measured by the slope of the curve, appears to increase as moisture availability increases (Figure 4).

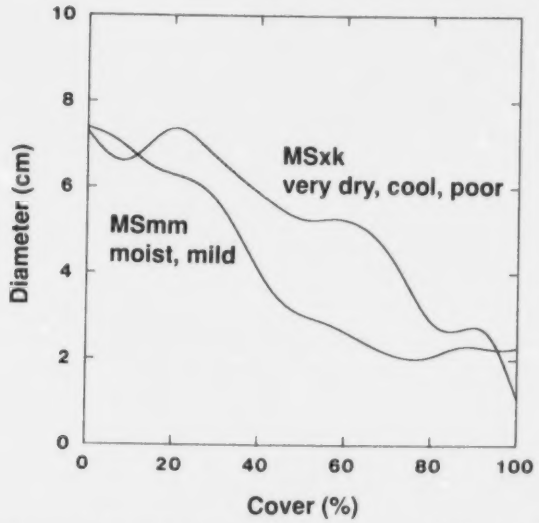

FIGURE 3. Relationships between lodgepole pine stem diameter and Sitka alder cover. The competition threshold is at approximately 70% Sitka alder cover in the MSxk subzone and only 30% in the MSmm subzone.

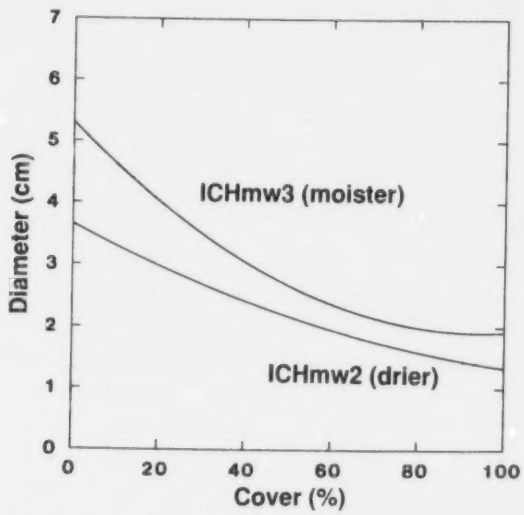

FIGURE 4. Relationships between Douglas-fir stem diameter and paper birch cover in the ICHmw subzone. The competitive ability of birch is greater in the moister ICHmw3 variant than in the drier ICHmw2 variant.

Understanding the Dynamics of Competing Root Systems

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Survival and growth rates of conifer seedlings in California and southern Oregon are tied to the soil moisture available during the growing season. Soil moisture during the summer is never plentiful because of the Mediterranean climate. The ability to acquire soil water depends on the plant's root absorptive capacity, total root area, rooting density, and microbial associations. Because water moves laterally very slowly through the soil profile, soil water acquisition also depends on the root's ability to grow into areas with moisture. The interactions of plants as they divide a finite site resource among themselves are referred to collectively as competition. This is the means by which resources are allocated and growth of some elements of the plant community are enhanced at the expense of others.

Vegetation management is the intervention in this process of resource allocation to favour conifer seedlings and species that are less competitive with the conifer seedling than others. Through vegetation management, the type and amount of competing vegetation should be controlled with predictable results and benefits to the desired species. However, competing vegetation cannot be managed with predictable results or benefits because of our lack of understanding of : root growth and development for conifer seedlings and competitive species; the basic mechanisms of root system interactions; the dynamics of vegetative competition above- and below-ground; the interactions of competitive species type and amount and conifer seedling survival and growth rates; or the potential to increase a conifer seedling's competitive ability.

Research is under way to investigate root system interactions, crown-root interactions, and conifer seedling competitive enhancement. The research approach is to use controlled greenhouse and field studies involving Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), ponderosa pine (*Pinus ponderosa* Dougl.), greenleaf manzanita (*Arctostaphylos patula* Greene), and deerbrush ceanothus (*Ceanothus integerrimus* H. and A.). As information is gained for these species, research will also be done to determine if root growth and development and water acquisition characteristics can be extrapolated to related species.

ROOT SYSTEM INTERACTIONS

Research involves determining the basic mechanisms of root-system interactions between conifer seedlings and brush species. Specifically we will determine: 1) the spatial and temporal interactions of conifer seedlings and brush species when species are grown separately and in combination; 2) the rate and absolute levels of depletion of the water resource by roots of different species; 3) whether modifying the timing or degree of water use by competing species alters the extent of physiological adjustment and compensation by conifer seedlings; 4) whether roots of conifer seedlings and brush species are associated through grafts or common bacteria or fungi; and 5) whether hydraulic lift (at night, water absorbed by deeper roots is transported to and lost from roots into drier upper soil layers) occurs with conifer seedlings and brush species. Once the basic mechanisms of root structure and function are understood, this information will be used to develop strategies for vegetation management which favour the conifer seedling and species of brush that are less competitive with the conifer seedling than other species would be.

CROWN-ROOT RELATIONSHIPS

Research will identify crown characteristics of conifer and brush species which reflect their root's lateral extent and water-absorbing potential. If crown characteristics can be used to indicate when root systems of adjacent plants are in close proximity, and therefore, in competition, then the number and intensity of vegetation management treatments can be tailored accordingly. If crown characteristics do reflect a root system's water absorbing potential, the information may be useful to indicate the effect of a treatment or the differences in treatment effect between species.

SEEDLING COMPETITIVE ENHANCEMENT

Research will determine the relationship between a seedling's inherent root growth potential and its ability to compete for moisture. Research will also determine if the inherent root growth potential can be enhanced by an application of fertilizer which fills in the nutrient gaps of the site. A seedling that has a vigorous root system, whether because of inherent or enhanced potential, should be a stronger competitor for soil water and other site resources than a seedling with a less vigorous root system. This information may allow a reduction in the number and/or intensity of vegetation management treatments.

Salmonberry Clone and Stand Structure, and Response to Disturbance in the Oregon Coast Range

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Salmonberry development following clearcutting and site preparation can be one of the most difficult vegetation management problems in the Oregon Coast Range. The most critical problems result from salmonberry's ability to regenerate vegetatively and rapidly dominate a site after harvesting, site preparation, or similar disturbances. The ability of salmonberry to respond to disturbance is based on its presence prior to harvesting, the impact of disturbance on its bud bank, and its ability to compete for resources in the disturbed area.

The morphological basis for salmonberry response is the large bud bank. This bud bank is dynamic, with new buds being added as the rhizome system expands and as new ramets are produced. Deletions occur as buds produce new shoots and as buds die. Most buds originate directly from the development of the primary meristem. The bud bank can be divided into several components based on physical location, susceptibility to damage, age, and potential for and rate of shoot production. The components are buds present on the intact or damaged above ground stem; and buds on the buried part of the lower stem, root crown and root. The largest and most complex part of the bud bank is located on the spreading rhizome system.

Salmonberry management has most commonly been achieved through a combination of slashburning and herbicides. Salmonberry response to fire is highly variable and depends on fire intensity and salmonberry stand and physiological condition. Herbicides can provide effective control, but their use is limited on some lands. Because of limitations placed on the use of slashburning and herbicides, it has become important for us to understand better the morphology and growth of salmonberry and its response to disturbances such as harvesting and manual control. Over the last 4 years, we have initiated several studies to provide answers to some of these questions. The scope and preliminary results of these studies are briefly discussed below.

SALMONBERRY CLONE AND STAND STRUCTURE

We have studied the above- and below-ground structure of clones and stands in clearcuts of different ages, in alder stands and conifer stands on upland sites, and in riparian areas in the Oregon Coast Range. Below-ground clone and stand structure were affected by overstory type. Salmonberry rhizome length in clearcuts was greater than in alder stands, and in alder it was usually greater than in conifer and riparian stands. Clone size was greatest in alder stands and clearcuts; clone shape in alder stands and clearcuts was relatively circular with frequently branched rhizome systems; in conifer stands clones were linear and there was little branching or rhizomes. Above-ground stand structure (uneven-aged/sized) was

very similar in all stand types except young clearcuts. Underground rhizome length and biomass can be predicted from basal area of the overstory or from salmonberry stem basal area.

SALMONBERRY RESPONSE TO MANUAL CUTTING

Because of the restrictions on the use of herbicides on federal lands, manual treatment of salmonberry, usually with chainsaws, has become a common method of plantation release. The effectiveness of this treatment depends on retarding the regrowth of salmonberry to the maximum extent possible and thus providing the biggest "window" possible for conifer response. Our study examined the effect of time (month of the year or stage of development) on the rate and type of salmonberry regrowth (height, percent cover, and stand characteristics). We cut salmonberry at monthly intervals from February to October 1988 and February 1989. Other treatments included in the study were designed to put maximum stress on the bud bank by removing all buds at monthly intervals, and to force the response of the rhizome bud bank by removing the stem and root crown components of the bud bank. The study was conducted on nine sites on the Siuslaw National Forest which were scheduled for operational treatment.

Preliminary results indicate that cutting from June to September retards regrowth, with cutting in the June-July period being the most effective. The most severe treatment in this study (i.e., the monthly removal of developing buds) did not eliminate salmonberry. However, once the stress of chronic bud removal disappeared, recovery began, although it was at a much reduced rate compared to regrowth following a single cut.

ROOT AND SHOOT DEVELOPMENT OF RHIZOME SECTIONS

The rhizome system contains most of the bud bank. The response of rhizome buds in highly variable because of factors such as rhizome age, proximity to a ramet, depth in the soil, and timing and type of disturbance. The objective of this study was to examine the development of new shoots and roots on rhizome sections (20 cm long) collected at different times of the year. Collections were made at the same time that the stands in the manual response study were treated. Four stands were used in this study. Rhizomes were incubated in a growth chamber under a 60°C temperature regime and 16 hours of weak light.

The results of this study indicate that there is no time of the year when shoot and root production do not occur. However, there was a significant effect of time of collection on both the percentage of rhizome sections which produce shoots and the number of shoots produced per section. The percentage of sections producing shoots reached a low point in June, but recovery occurred rapidly. The number of shoots produced per section was uniformly low from May through September; levels of shoot production were 2-3 times greater before May and after September. The proportion of rhizomes producing roots reached the lowest levels in April and May and was highest in September. The number of roots per section was greatest from August to October and uniformly low the rest of the year. Rhizome activity in this study exhibited a pattern of activity that was generally similar to that of the manual cutting study. The low points in shoot production in this study and recovery from mechanical treatment were associated with the lowest seasonal levels of total available carbohydrates.

SUMMARY

The results of these studies provide us with information that will enable us to begin predicting salmonberry response to disturbance. Rhizome length in various forest types can be predicted from overstory basal area and salmonberry basal area. This information, combined with that on bud bank populations and salmonberry recovery rates, can provide estimates of potential cover development and stand development. More information will be needed on the effect of harvesting and site preparation on bud condition, so that we can refine any estimates from the data already available.

POSTERS

Vegetation Control and Seedling Response

Controlling Aspen Suckering with Pre-harvest Treatments

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THE PROBLEM

Aspen (*Populus tremuloides*) tends to regenerate quickly by resprouting following stand harvest. As a result, free growth of the regenerating stand may be delayed because of high aspen densities. Traditional post-harvest treatments control aspen after the suckers have been developed. An alternative pre-harvest control treats the source of suckers to reduce potential competition. To date, the effectiveness of these operational treatments has been inconsistent.

Under FRDA project 3.60, a trial was established to compare two pre-harvest aspen control methods – stem injection of glyphosate and manual girdling – done at 2 and 4 years prior to harvest. It is hoped that this will determine the optimal period between control and harvest for the two treatments.

ASPEN REPRODUCTIVE CHARACTERISTICS

Aspen regeneration from seed is rare despite prolific seed production, primarily because moisture conditions of the seedbed during germination are unfavourable. Aspen commonly regenerates from suckers that emerge from shallow lateral roots (2.5-10 cm deep). Suckers can originate along these roots up to 24 m from the original stump.

Suckering is inhibited by hormones called auxins, which are produced in growing branch tips; and suckering is initiated by cytokinins, which are hormones produced in the roots. Cutting aspen stems, therefore, promotes suckering by shifting the ratio of cytokinins to auxins in favour of the sucker-stimulating cytokinins. Canopy removal also promotes suckering because the effectiveness of cytokinins is enhanced by increased soil temperature.

CHEMICAL CONTROL: HACK AND SQUIRT

Glyphosate (Vision® or Roundup®) is the chemical most widely used for controlling aspen in British Columbia. Treatment should occur after the active growing season when transport of chemical to the roots is greatest. For effective control, 1 mL of 100% Vision® per 5 cm dbh is recommended. The chemical causes death by interrupting the creation of essential cyclic amino acids.

MANUAL CONTROL: GIRDLING

Girdling entails the removal of a band of bark and cambium around the tree. By blocking the transport of photosynthates, girdling starves the roots and kills the tree. The cambium must be completely severed for girdling to be effective. Girdles that encircle the stem should be greater than 2 cm wide and 0.3 mm deep or deep enough to sever the cambium. To hasten mortality, they should be cut when root reserves are lowest.

EXPERIMENT

A controlled experiment was set up to assess the comparative suitability of hack-and-squirt and girdling methods in reducing aspen suckering after harvest. The three objectives of the project are: 1) to determine the efficacy of hack-and-squirt and manual girdling in reducing post-harvest suckering; 2) to determine the effects of treatment method and interval between treatment and harvest (2 and 4 years) on suckering; and 3) to determine the impact of the treatments on internal rot and snag use by cavity-nesting birds.

Plots were laid out in the fall of 1988 on a site 30 km northwest of Kamloops. The site is located in the MSxk subzone of the Montane Spruce (MS) zone, and the stand is predominantly Douglas-fir and lodgepole pine, interspersed with aspen.

Six of the 15 plots were treated in year 1. All aspen in three plots were girdled in the spring of 1989 and the aspen in three other plots were treated chemically in the fall of 1988 according to the manufacturer's suggested rate. Timing was chosen to provide the most effective control. The second set of treatments will take place in the fall of 1990 and spring of 1991. Untreated controls have been established for comparison. The site will be logged in 1992/93.

The vigour, height, and dbh of target trees and of any suckers that develop have been assessed for 2 years, and subsequent assessments will be made yearly until 1-year post-harvest. Cavity-nester use and internal rot of the targets aspens were assessed in June 1989 and will be assessed again in the fall of 1992. Further post-harvest assessments will be made 5 and 10 years after logging to determine if there is greater mortality from suckers in treated areas as a result of weakened root reserves.

Results on suckering are not yet available, but the 1st-year aboveground control by hack-and-squirt was nearly 100% of the trees treated. Effects of girdling are not yet detectable.

The Growth of White Spruce (*Picea glauca* (Moench) Voss) Seedlings in Mechanically Prepared and Untreated Planting Spots in North Central British Columbia

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This poster summarizes end-of-the-growing-season observations made on white spruce seedlings for 3 successive years. The three sites, Iron Creek (located 120 km northwest of Fort St. John), Stewart Lake (located 50 km west of Dawson Creek), and Mackenzie were prepared in the summer of 1986, then planted in May - June 1987. The populations reported represent part of the seedlings planted for FRDA project 1.10 (L. Bedford). Most of the data for the first 2 years were collected by Mr. M. von der Gonna. The authors thank Mr. Bedford and Mr. von der Gonna for their contributions and co-operation.

White spruce seedling growth is strongly affected after outplanting by low soil temperatures and competing vegetation. Treatments were designed to compare the growth of seedlings (1) planted on the top of large mounds (which provided increased soil temperatures during the growing season and a microsite relatively free of competing vegetation) (2) planted on the hinge of a Bräcke patch (which provided slightly elevated soil temperatures and reduction of competing vegetation) and (3) planted on microsites which had not received a site preparation treatment (see Figure 1).

Untreated **Bräcke patch** **Ministry mounder**

FIGURE 1. The microsites and planting spots used in the experiment.

Post-planting field observations suggested there was a definite area x site treatment interaction. Plots on both the Iron Creek and Stewart Lake sites exhibited a water table so high that, for at least part of the growing season, the seedlings planted in the Bräcke patch were in pools of water. While the Mackenzie area did not have such a high water table, it was subject to growing season frosts, so that the healthiest white spruce seedlings were those that received some protection from radiation frosts under a light canopy of competing vegetation.

The data suggest that, while the seedlings on the mounds showed the greatest growth, at least part of their superiority at both Iron Creek and Stewart Lake reflected improved soil aeration as well as higher temperatures. The root form of the harvested seedlings generally reflected the configuration of the

original plug. Few of the seedlings had the typical root extension in the upper soil layers that characterize natural white spruce seedlings. The root elongation that did occur came invariably from adventitious roots originating from the seedling stem above the original root plug. There was little root elongation at any level of the plug when it was planted next to organic material incorporated into the soil by the site preparation technique, although seedling roots frequently thoroughly explored this media.

It should be noted that the soils on all three sites are very fine textured and the site preparation had an adverse effect on soil structure. Nonetheless, the present data suggest that the styroblock configuration employed in British Columbia nurseries is not compatible with the early establishment of a morphologically "natural" root system for white spruce seedlings.

Vegetation Response to Five Methods of Plantation Release in Northern California

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A major silvicultural challenge of the 1990's will be to ensure that every acre in conifer plantations will be growing at or near the potential of the site. Large increases in population and alternative uses for the land emphasize the need for full production on every available acre.

Non-crop vegetation has the potential not only to keep a plantation from reaching full productivity, but also to keep it from yielding merchantable products. Many species of grasses, forbs, and shrubs are superbly adapted to dominate in newly disturbed areas. Certainly, they are better adapted than pines and firs from nurseries that are placed minus part of their root systems in an often inhospitable environment. Weeds often interact with insects and animals and synergism may lead to even greater conifer seedling losses.

The best strategy is to *prevent* competition during the establishment period, but if that cannot be accomplished, early release of the plantations must be accomplished through minimizing the effect of this competition early in the life of the conifer seedling.

Our research program concentrates on release because, at least in California, non-crop vegetation is almost always present. As part of a National Administrative Study, we began to evaluate methods for releasing young conifer plantations on forest lands in northern California in 1980. Grazing animals, manual control, a new generation of herbicides, mulches (collars), and large machines such as rotary masticators were techniques we tried. Thirty-five study sites on federal, state, and private lands have been established.

From the results of our studies, we have made several findings:

- If growth is to be at the potential of the site, release is a must.
- The most effective time to release is the 1st year after planting.
- Stem caliper is consistently the best indicator of release.
- Treatments with a radius smaller than 1.5 m around crop seedlings are ineffective for increasing growth.
- Newer, non-phenoxy herbicides are cost-effective.
- Manual release from sprouting shrubs is rarely cost-effective.
- Manual release from forbs, grasses, and seedling shrubs is effective, but costly.
- Mechanical release without follow-up herbicide is ineffective.
- Large mulches (3-m square) show promise.
- Grazing substantially reduces shrub cover and height with little gain in pine growth.

Effects on Brush Control from the Addition of Adjuvants to Glyphosate[1]

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ABSTRACT

A field study carried out over a period of 2 years in forest plantations in northern Ontario showed that addition of several adjuvants to commercial formulation of Vision® (glyphosate) at low volume rates (30-180 L) does not significantly improve efficacy. It is suggested that no benefits would be gained from addition of adjuvants when Vision® is aerially applied at low volume rates.

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[1] This work was completed at the Forest Pest Management Institute, Forestry Canada, Sault Ste. Marie, Ontario, while the author was on staff there.

The Coastal Reforestation Systems Study: Comparing Alternatives

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In 1975, the Siuslaw National Forest and the Pacific Northwest Research Station jointly initiated a large research and development effort to evaluate different combinations of reforestation techniques applicable in coastal forests of the Pacific Northwest. Quantitative information was needed on the interacting effects of site preparation, stock type, animal protection, and release in the establishment and growth of trees and competing vegetation.

Factorial comparisons were made in operational-size trials involving four site preparation methods, stock of two species tubed or not tubed as protection from animals, and released or not released by aerial spraying when vegetation was 3 years old. Nursery stock tested included five classes of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and two of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The treatment combinations, 112 in all, were applied side-by-side as complete replications on six clearcuts located in the Coast Ranges from north of Hebo to southeast of Florence, Oregon.

RESULTS

After 7 years, survival for all species and classes of stock combined averaged 68%, and total height averaged 275 cm. There were large differences among treatments. The highlights of the main effects are listed below.

Protection by plastic mesh tubing:

- Survival was higher for protected trees than for unprotected trees – 84 vs. 53%.
- Protected trees were 8% taller than unprotected trees.

Site preparation:

- Survival was highest in areas subjected to a preburn aerial spraying and later broadcast burning – 75 vs. 62% for no site preparation. Tree survival was intermediate for either spraying or burning alone.
- Site preparation benefited unprotected trees more than it benefited protected trees. Survival of unprotected trees ranged from 43% with no site preparation to 61% for the spray-and-burn preparation. Among protected trees, survival ranged from 80% with no site preparation to 89% for the spray-and-burn preparation.
- Total height was 21% greater after spray-and-burn site preparation than after no site preparation.

Stock class:

- Survival and total height of all five classes of Douglas-fir stock were greater than for the two classes of western hemlock stock.
- Survival and growth of Douglas-fir were in direct proportion to initial size: the larger the stock, the greater its survival and total height. However, the

differences between the largest and smallest seedlings were relatively small. Survival ranged from 76 to 66% and total height ranged from 321 to 268 cm.

Vegetative competition:

- Before site preparation, total cover on the study areas averaged 56%. Woody species composed about two-thirds of the total cover.
- Spraying and burning reduced the woody cover to 1%, burning alone reduced woody cover to 12%, and spraying alone reduced woody cover to 32%. Natural changes reduced cover in the areas not site prepared during the same period from 42 to 29%.
- By the 7th year, average conifer cover was 12% in areas that had not been site prepared, 19% in sprayed areas, 21% in burned areas, and 28% in sprayed and burned areas.

APPLICATIONS

Results of this integrated study show that site preparation can improve subsequent tree survival and growth and reduce the level of competition from woody species for several years. Where damage from animals, particularly from mountain beavers (*Aplodontia rufa*) is high, protection of trees with plastic mesh tubing can substantially improve tree survival. Protection of trees is not as critical when sites are prepared by burning as when they are not. Development of Douglas-fir plantations can be maximized in coastal conditions by broadcast burning residues after a pre-burn spray, planting large stock, and preventing serious damage from animals. With this prescription, good plantations can often be obtained without any subsequent need for release.

Site Preparation on Coastal Sites

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Several site preparation methods have been used to reduce competing vegetation and foster conifer establishment and growth in coastal forests of the Pacific Northwest. The use of fire and chemicals has been questioned because of costs and environmental concerns. Side-by-side comparisons of site preparation methods were needed to determine their relative biological effectiveness and costs.

Six site preparation methods were compared in an operational-sized, replicated experiment to determine their effects on the survival and growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and associated vegetation in the Coast Ranges of Oregon. The methods applied to 5-acre plots included no site preparation, manual cutting of woody vegetation, aerial spraying with glyphosate, broadcast burning, and manual slashing of residual vegetation or aerial spraying it with Tordon® 101 followed by broadcast burning. Every other tree was protected from animal damage by plastic mesh tubing. Designated 2-0 Douglas-firs and associated vegetation were observed periodically.

RESULTS

After 7 years, 76% of all trees planted were still alive. They averaged 386 cm in total height and 66 mm in stem diameter measured 15 cm above ground level. Site preparation and protection significantly affected tree and vegetation development.

Site preparation:

- Survival was higher in all burned areas (81.8%) compared with areas that were not burned (70.3%) (P=.02). Survival in aerially sprayed areas equalled survival in sites that were broadcast burned.
- Seedling height for site preparation methods involving burning or aerial spraying did not differ from each other but differed from spot-clearing or no site preparation (P=.05) (Figure 1).
- All but one of the site preparation methods resulted in increased stem diameter. Manual spot-clearing proved to be no better than no site preparation.

Protection by plastic mesh tubing:

- Survival of protected trees was substantially higher than for unprotected trees, 83 vs. 69% (P=.0001).
- Total height of protected trees was greater than for unprotected trees, 400 vs. 372 cm (P=.0002).
- Stem diameter of protected trees was slightly larger than for uprotected trees, 69 vs. 64 mm (P=.0005).

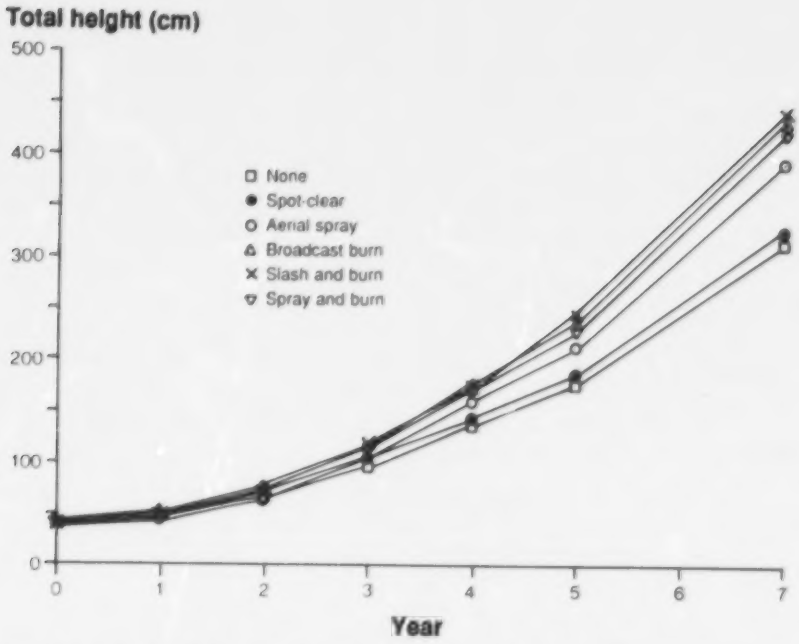

FIGURE 1. Average total height of Douglas-fir after different site preparations.

Vegetative composition:

- Seven years after site preparation, cover of Douglas-fir was 38%. Cover of Douglas-fir was about twice as great where sites were prepared by burning or spraying compared with sites that were spot-cleared or not site prepared.
- Salmonberry cover was lowest on areas subjected to spraying but was also low in areas that were broadcast-burned or slashed and burned.

Relative costs:

- Broadcast burning yielded the highest volume return relative to the base costs associated with no site preparation.
- Compared to no site preparation, methods involving broadcast burning produced 4.4 times more volume when trees were protected from animals and 5.2 times more volume when trees were unprotected. Aerial spraying produced 3.5 times more volume.

APPLICATION

Site preparation methods involving broadcast burning or aerial spraying of herbicides clearly improved tree survival and enhanced growth through the 7th year. Furthermore, the gain in volume has been greater than the increase in costs needed to produce that gain. These study sites, where salmonberry were well-established before the conifer-alder stands were harvested and mountain beaver are common, are representative of the most difficult coastal areas to reforest. By use of site preparation, good quality stock, and protection from animals, rapidly growing plantations can be obtained in such areas, often without any need for release.

Pre-harvest Prescribed Burning for Vegetation Management

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Successful conifer regeneration in western forests commonly requires control of competing vegetation. However, current methods of vegetation management in plantations often have one or more limitations, including environmental and personal safety risks, political constraints, ineffectiveness, damage to conifer seedlings, and high costs. To help address this problem, the USDA Forest Service's Vegetation Management Research and Development Program, headquartered at Redding, California, has as part of its mission "to develop and evaluate alternative methods for preventing or controlling competing vegetation." Among the research areas included in the R&D Program are vegetation management strategies that incorporate prescribed burning. Pre-harvest prescribed burning is one such strategy that has shown early promise as a means of reducing competing vegetation problems during the plantation establishment period.

A study was conducted in a 70-year-old California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.) stand in northeastern California to gain more information about the potential efficacy of pre-harvest burning. The study addressed the question of the disposition of viable shrub seeds stored in duff and soil which, following normal harvest and site preparation activities, can germinate and produce a serious competition problem. Densities of snowbrush (*Ceanothus velutinus* Dougl. *ex* Hook.) seedlings the year after prescribed burning varied significantly with burn depth (level of consumption), peaking at 410 000 seedlings/ha in moderate-consumption areas in thinned stands. Few seedlings were found in the deepest burns. Sampling of vertical profiles of dormant shrub seeds in duff and soil indicated a mean density of 12.8 million snowbrush seeds per hectare in unburned stands. A peak density of 2.7 million seeds per hectare occurred in the lower 2 cm of duff alone. Densities of snowbrush seeds were not reduced significantly in areas of moderate burn depth. In areas of deep burn, however, 94% of seeds were destroyed to a depth of 10 cm in the soil, with no viable seeds remaining above the 4-cm depth in the soil. Preliminary data suggest similar relationships between depth of burn and seed mortality in a range of mixed conifer sites.

In many cases, live shrubs already present in a stand before harvest are at least as much of a concern for subsequent competition with conifer seedlings as are stored shrub seeds. Another study (conducted by Kauffman and Martin at the University of California, Berkeley) under a co-operative agreement with Weatherspoon, investigated the potential benefits of pre-harvest burning for killing or reducing the vigour of shrubs already weakened by their understory position in the stand. The experimental prescribed burns, conducted at three sites in the Sierra Nevada mixed conifer type, varied in season and level of consumption. Burns conducted during late spring and early fall were characterized by high consumption of duff because of the relatively low duff moisture contents prevailing at those times. Moderate-consumption burns were those conducted during early spring and late fall. While top-kill of shrubs was very high in all burns (90-100%), shrub mortality (defined as no resprouting after 2 years) was greater in high-consumption burns (mean 70%, range 44-88%) than in moderate-consumption burns (mean 40%, range 21-75%). Heat release around shrub bases associated with level of consumption appeared to be a more important factor in shrub mortality than season-related phenology.

Available evidence indicates that deep or high-consumption prescribed burns are more effective than moderate-consumption burns in reducing stored seed reserves and in killing live shrubs in a forest stand. Deep burns, however, may produce unwanted effects. Possible soil damage – a particular concern – will be addressed in future studies. However, deep understory burns are likely to have less impact on soils

than (1) consumptive, mineral soil-baring fires that historically favoured regeneration establishment in most coniferous forest types, or (2) machine piling of slash, a practice widely used for site preparation.

The results to date are encouraging, though it remains to be seen whether pre-harvest prescribed burning has any real practical or operational value in vegetation management. To address this question, we are initiating a long-term, large-scale study that will incorporate a series of regeneration regimes beginning before harvest and continuing through plantation establishment. Alternative pre-harvest, site preparation, and release treatments will be tested in a number of combinations. Relative effectiveness of the various regimes will be measured by conifer seedling performance and levels of competing vegetation in the plantation.

POSTERS

Microclimate Considerations

Temperature and Moisture Regimes in Mid and High Elevation Clearcuts

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PROBLEM

Weather conditions can cause serious problems for reforestation in the Coast/Interior transition zone. Problems range from low soil moisture during the summer to frequent frosts during the growing season. However, the magnitude and frequency of these events is unknown.

OBJECTIVES

This project had three major objectives: (1) to monitor the microclimate at selected sites in the Coast/Interior transition zone; (2) to compare these data with the survival and growth of seedlings planted at the sites; and (3) to provide data to develop and verify a model to assess soil water availability at sites and determine planting windows.

STUDY SITES

The atmospheric and soil weather conditions are being measured in clearcuts in the Ryan River, Hurley River, and Hope Creek valleys in south western British Columbia. The sites presented here are in the CWHc1, MSb1, and ESSFf biogeoclimatic subzones*, respectively. Two other sites are also being monitored as part of this project (FRDA Project 2.03). Data loggers are used to obtain daily summaries of weather conditions. Growth and survival of Douglas-fir and spruce seedlings are being monitored.

RESULTS

Selected soil and air temperature and soil moisture conditions at the sites are graphed in Figures 1-3.

The Ryan River site (350 m elevation, 27% slope, SE-facing) is located on a coarse-textured, gravelly soil (60% coarse fragment content). Winter snow pack (November to March) is shallow (<0.3 m), and the seedlings are often exposed to the air in winter (Figure 1). Spring and summer rainfall is frequently low

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* CWH – Coastal Western Hemlock Zone.
MS – Montane Spruce Zone.
ESSF – Engelmann Spruce Subalpine Fir Zone.

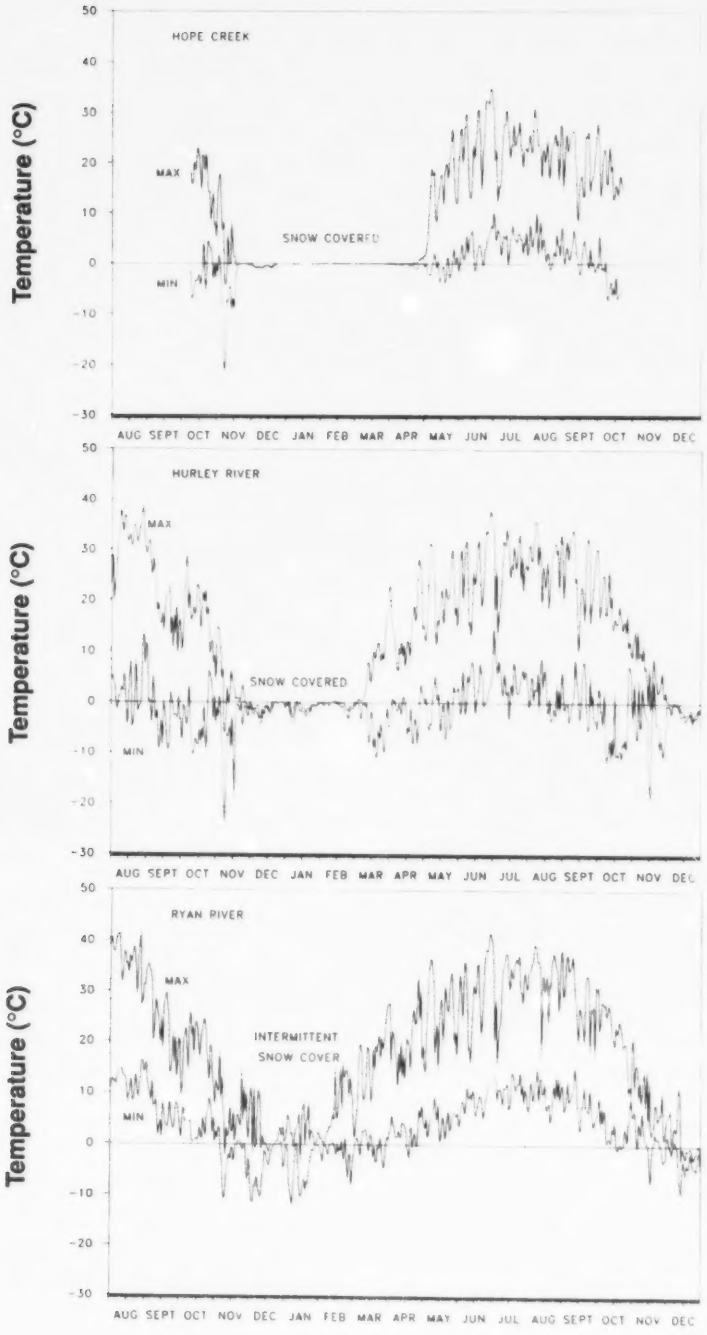

FIGURE 1. Daily maximum and minimum air temperature at 0.25 m (top of seedling) for the Hope Creek, Hurley River, and Ryan River sites, August 1986 to December 1987.

(Spittlehouse and Childs 1989). This factor, combined with the low water storage capacity of the soil (Spittlehouse and Stathers 1989) and the use of water by the competing vegetation, often results in soil water potentials of -0.3 to -0.5 MPa (3 to 5 bar) in June (Figure 2). Those seedlings that survive grow slowly. April to October air temperature ranges from 5 to 40°C (Figure 1). Root zone soil temperature is not a concern, averaging between 10 and 20°C from April to October.

The Hurley River site (1128 m, flat) has a coarse-textured, gravelly soil (20% coarse fragments), similar to that of the Ryan site. Much of the slash and the surface organic layer were removed by burning prior to planting, producing good control of vegetation. The snow pack at this site is deeper and lasts longer (November to April) than at the Ryan site. Late spring and summer rains are higher and soil moisture is rarely a problem (Figure 2). Dense competing vegetation may result in moisture depletion during mid-summer. A major climatic limitation at this site is the regular occurrence of summer frosts (Figure 1). These frost events are related to radiative cooling under clear skies, probably compounded by the down-valley flow of cold air draining from the high elevations and pooling on the flatter valley bottom (Stathers 1989). Daytime maximum air temperatures are about 2°C cooler than the Ryan site (Figure 1). The blackened soil surface can have a high temperature on sunny days. Root zone soil temperatures average 10-15 °C from late June to September (Figure 3).

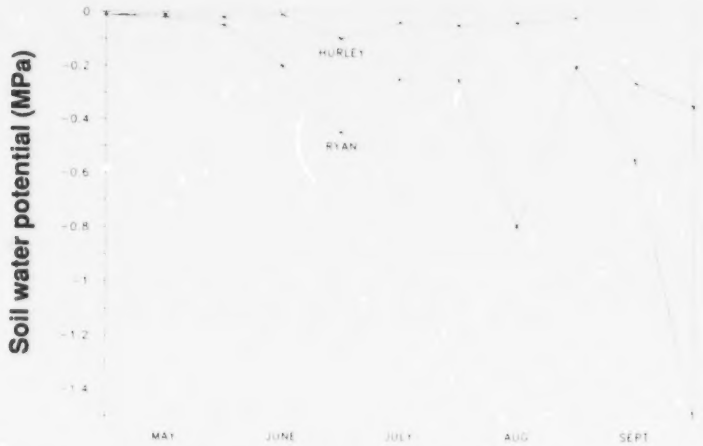

FIGURE 2. Average soil water potential (MPa) in the seedling root zone (0-0.2 m) for the Ryan River (+) and Hurley River (x) sites, May to September 1987. Hope Creek is not shown, since water potential varies between -0.01 and -0.05 MPa.

The Hope Creek site (1341 m, 27% slope, NNE-facing) is also on coarse-textured, gravelly soil. The site was burnt prior to planting, though the burn was not as intense as that at the Hurley River. This site has the deepest (about 1 m) and longest-lasting (November to late May) snow pack (Figure 1). Soil moisture is not a problem, even with competing vegetation, because of down-slope seepage of water and frequent rainfall. Summer frosts are not as common as at the Hurley site, probably because of the drainage of cooling air off the sloping site. Daily maximum air temperatures are similar to those at the Hurley site. Rapid development of competing vegetation is beginning to restrict the light reaching the seedling and may also result in vegetation press. Soil temperatures are cooler than at the Hurley site, averaging 10-12°C from July to September.

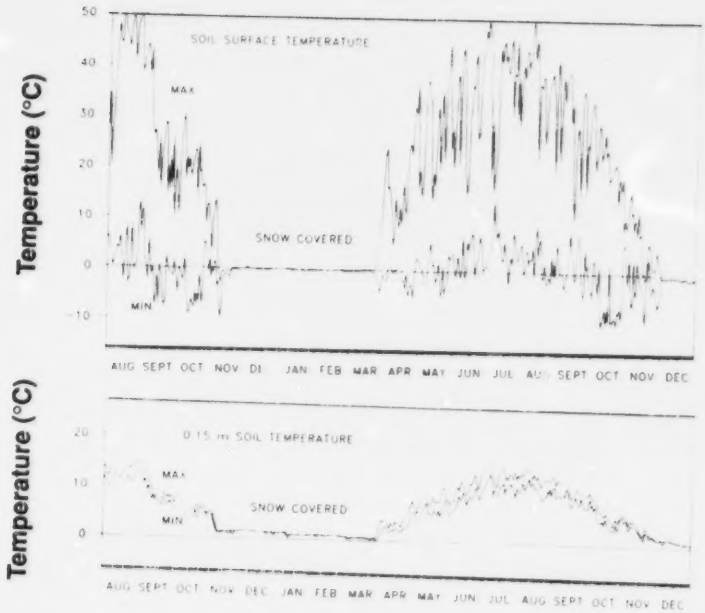
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FIGURE 3. Daily maximum and minimum soil surface and seedling root zone (0-0.2 m) temperatures for the Hurley River site, August 1986 to December 1987.

MODELING SOIL MOISTURE

The model is physically designed to work from limited site and weather data (Spittlehouse and Goldstein 1989, and this paper). The site data required are latitude, longitude, elevation, slope, aspect, soil texture, stone content, root zone depth, vegetation classification, and vegetation cover. The weather data required are daily maximum and minimum air temperature and rainfall.

Variation in the May to September soil moisture conditions for 1908 to 1965 was determined using the model for the Ryan River site (Spittlehouse and Childs 1989). The simulations indicated that the site was too dry for seedling survival in 17% of the years. There was adequate moisture only 33% of the time. The remaining 50% of the years are considered marginal. Successful reforestation in these years would depend on the amount of vegetation competing for the soil water and the distribution of the rainfall. The analysis suggested that fall planting had a greater chance of success because of the wetter conditions (September rainfall).

SUMMARY

Environmental data illustrate the regular occurrence of adverse weather conditions on sites in the Coast/Interior transition zone. Frequent low soil moisture conditions restrict seedling survival and growth at the Ryan River site (Figure 2). The computer model suggested that this situation could occur 77% of the time. The high elevation sites studied do not have soil moisture problems but are limited by summer frost (at the Hurley River site) and a short growing season (at the Hope Creek site) (Figure 1). Low root zone soil temperatures may also be a problem for part of the year at these sites. The computer model is capable of providing data on site moisture conditions to aid reforestation decisions.

REFERENCES

Spittlehouse, D.L. 1989. Impact of competing vegetation on site water balance. *In* Vegetation Competition and Responses: Proc. 3rd Annual Vegetation Management Workshop. E.A. Hamilton and S.B. Watts (editors). B.C. Min. For., Victoria, B.C., FRDA Rep. 026, pp. 28-30.

Spittlehouse, D.L. and S.W. Childs. [1990]. Soil moisture after site preparation. *In* Sustained Productivity of Forest Land: Proc. 7th N. Am. Soils Conf., Vancouver, B.C. In press.

Spittlehouse, D.L. and M.J. Goldstein. 1989. Modelling soil water availability for seedling establishment. *In* Climate applications in forest renewal and forest production. D.C. MacIvor, R.B. Street, and A.N. Auclair (editors), Environ. Can., Atmos. Environ. Serv., Downsview, Ont., pp. 117-126.

Spittlehouse, D.L. and R.J. Stathers. [1989]. Seedling microclimate. B.C. Min. For., Victoria, B.C. Land Manage. Rep. 65. In press.

Stathers, R.J. 1989. Summer frost in young plantations. B.C. Min. For., Victoria, B.C. FRDA Rep. 073.

Microclimate of Mounds and Seedling Response

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PROBLEM

There are often significant regeneration problems with white spruce on relatively high yielding sites in the Sub-Boreal Spruce and Engelmann Spruce-Subalpine Fir zones in the interior of British Columbia. Dense shrub and ladyfern communities, 1-2 m in height, can develop within 3 years after harvesting. Slopes of 15-20%, high soil moisture, and large volumes of residual debris can constrain mechanical site preparation. Fall burning windows are short and inconsistent, and chemical control of the vegetation may not be appropriate. Major biological constraints to early spruce survival and growth are low soil temperature, excessive soil moisture, low soil aeration, limited light availability, and vegetation and snow press.

OBJECTIVES

The objective of this study was to determine whether or not mounding treatment could improve survival and growth of white spruce seedlings. This was achieved through the measurement of the aerial and soil microclimate of mounds; measurement of the physiological and growth responses of white spruce seedlings; and comparison of the mounding treatment with other treatments.

SITE

The site is in the valley of the Bowron River, 75 km ESE of Prince George, B.C., 1100 m in elevation, on a 15% NE-facing slope (53° 40' N, 123° 40' W). It was classified as Spruce Devil's club site (SBSf/01). The site was logged in winter 1981/1982, treated in late August 1983, and planted in late May 1984 with 2+1 bareroot seedlings. Soils are gleyed, Grey Luvisols with 20% coarse fragments. The competing vegetation consists of a dense canopy of ladyfern, Indian hellebore, thimble-berry, devil's club and sitka alder. Above- and below-ground environmental variables have been measured for 6 years. Plant growth (biomass, height) and nutrients were measured for 5 years. Photosynthesis, transpiration and plant water potential were measured over 4 years as part of EP 966.

RESULTS

A schematic of the mounding treatment is shown in Figure 1. A summary of the improvements in seedling microclimate is presented in Table 1. Seedling response is summarized in Table 2.

The mounds create an open area about 0.6 m in diameter around the seedling. This opening allows 2-4 times as much sunlight to reach the mounded seedling and the soil surface as an untreated area. The mounded mineral soil dries out during the summer. However, the lower organic layer in the mound and the soil below the mound remain moist, supplying water to the seedlings. Mounding improves the soil

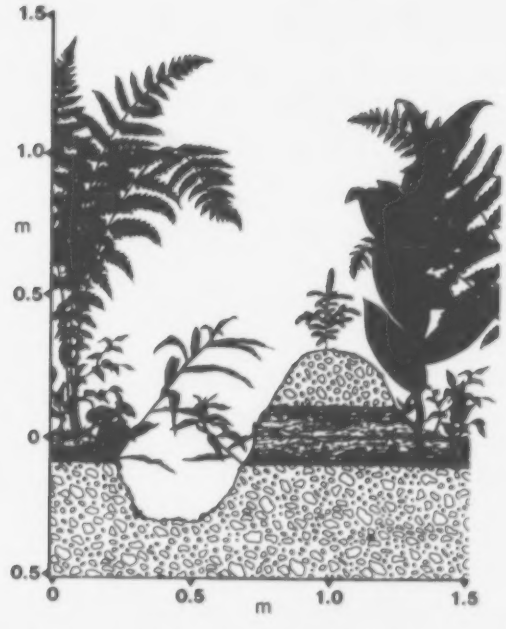

FIGURE 1. Schematic of mound showing the seedling and vegetation in year 1. The mound consists of 0.2 m of soil over an inverted humus layer, over "undisturbed" humus and mineral soil.

TABLE 1. A summary of the changes in seedling microclimate achieved by mounding

Light	2-4 fold increase, not limiting
Soil temperature	Doubling of growing degree days at 0.1 m, earlier warming in the spring
Soil moisture	Drier, no flooding of root zone, reduction in heat capacity
Aeration	0-0.2 m soil increased from 50 to 60%
Vegetation and snow press	Greatly reduced
Nutrients	Increased uptake

TABLE 2. Seedling response over 5 years

	Mounded	Untreated
Survival (%)	99.0	80.0
Height increment (m)	0.61	0.35
Shoot biomass inc.(g)	159.4	64.3
Form	Straight, bushy	Twisted, thin
Root growth	Extensive, rapid growth after planting	Slow growth after planting

thermal environment. Reduced shading, removal of the insulating organic layer, and a drier soil result in greater heating of the root zone of the mounded seedling (Draper *et al.* 1985, 1988; Binder *et al.* 1989; Spittlehouse and Stathers 1989).

PHOTOSYNTHETIC INDEX

Seedlings need adequate photosynthesis over the growing season to survive and grow. The environment influences the amount of photosynthate that the seedling can produce each day. Each weather variable has an optimum value around which it is non-limiting. There may be an interaction between certain variables. The photosynthetic potential of each variable for each day can be summarized in terms of a photosynthetic index. Each index is calculated with 0 meaning no photosynthesis for the day and increasing to 1 for the maximum rate with no limitations. These indices can be combined to give a single qualitative estimate of the effect of the environment on seedling photosynthesis. This index does not indicate how the seedling partitions or uses the photosynthate in growth, but it aids in explaining the response seen in Table 2.

The combined index for the mounds and an untreated area in 1987 are shown in Figure 2. Air and soil temperatures regulate the index for January to May and October to December. Light and vapour pressure deficit are occasionally limiting from June to September. Soil moisture limitations are negligible at this site. The lower indices in the untreated area are due to a lower soil temperature resulting from an insulating organic layer and a wet soil (May and June); and to lower light levels resulting from shading by competing vegetation (July to September).

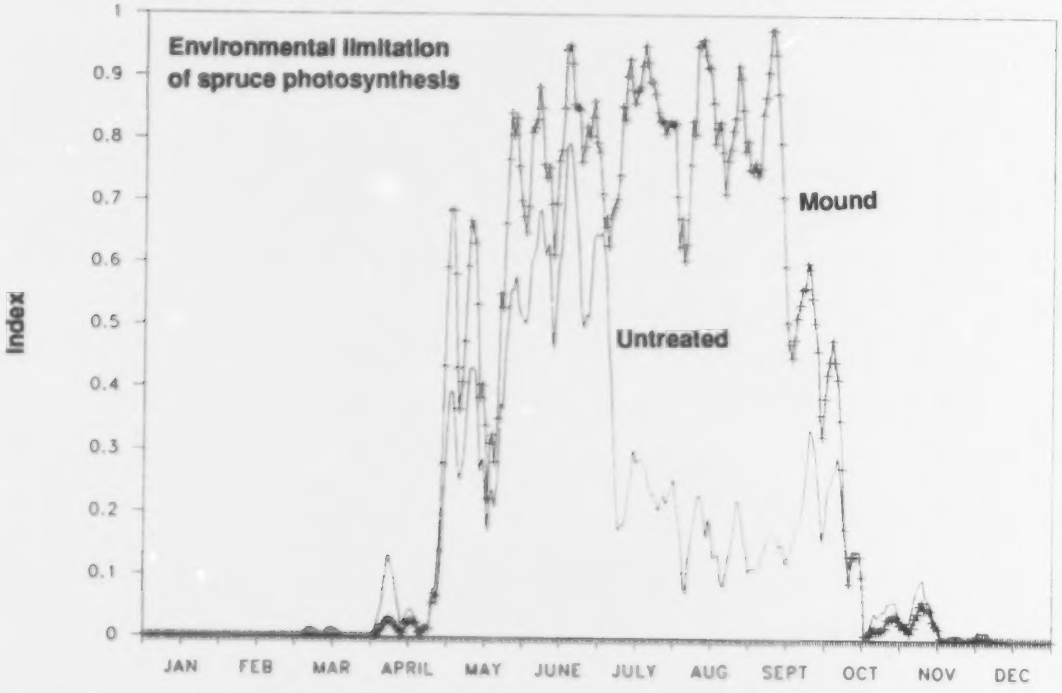

FIGURE 2. Five-day running average of the photosynthetic index for spruce seedlings growing on a mound (+) and in an untreated area (-). The index is a measure of the effect of the environment on the ability of spruce to meet its photosynthetic potential. It was calculated using weather data for 1987.

Measurements of root growth and above-ground biomass indicate that the greater amount of photosynthesis translates into greater growth (Table 2). Also, the improved soil conditions result in a more rapid root growth of the seedlings, immediately after planting.

SUMMARY

The mounds create an open area about 0.6 m in diameter around the seedling. This opening allows sunlight to reach the seedling and the soil surface. The opening also reduces the amount of vegetation that can fall on the seedling. The raised, exposed mineral soil dries, resulting in more rapid warming than the shaded, insulated untreated areas (Table 1). These improvements increase the potential for photosynthesis. The seedlings respond with improved survival and growth (Table 2).

REFERENCES

Binder, W.L., D.A. Draper, and D.L. Spittlehouse. 1989. Ecophysiology: post-planting physiological results and their implications for growing spruce. *In* Learning from the past, looking to the future. B.A. Scrivener and J.A. MacKinnon (editors). B.C. Min. For., Victoria, B.C., FRDA Rep. 030, pp. 33-35.

Draper, D., W. Binder, R. Falman and D. Spittlehouse. 1985. Post-planting ecophysiology of interior spruce. *In* Interior Spruce Seedling Performance - State of the Art, Northern Silvic. Comm., B.C. Min. Forests, Victoria, B.C., pp. F1-F20.

Draper, D.A, D.L. Spittlehouse, W.D. Binder, and T. Letchford. 1988. Field measurement of photosynthetically active radiation. *In* Proc. Combined Meet. Western Forest Nursery Associations. T.D. Landis (editor). U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Sta., Fort Collins, Col., Gen. Tech. Rep. RM-167, pp. 212-218.

Spittlehouse, D.L. and R.J. Stathers. [1989]. Seedling microclimate. B.C. Min. For., Victoria, B.C. Land Manage. Rep. 65. In press.

POSTERS

Floodplain Management

Hydrology of the Skeena River Floodplains: Implications to Vegetation Management

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This study was initiated to provide information to silviculturists and concerned members of the public about those environmental characteristics of the Skeena River floodplains that relate to the fate of forestry herbicides. The project was later expanded to describe the flooding processes of the lower Skeena and produce a flood hazard classification for planning silviculture treatments on the floodplains.

Data were collected on the annual groundwater regime and its driving forces, the stratigraphy of the deposits, the physical characteristics of the soil, the climatic regime of both air and soil, and the chemical and physical properties of certain herbicides. Inferences can be made about the probable fate of the herbicides in coastal alluvial environments. The period from late July to early September is identified as the safest for the application of herbicides because the water table is low and consequently the chances of flooding are low. The surface deposits of fine silts and the rapid incorporation of organic matter into the soil ensures low mobility of most herbicides.

The development of the flood classification was based on the relationship between the survival and growth of Sitka spruce (*Picea sitchensis*) and the frequency, duration, and depth of flooding. Elevation of planting sites explained a large proportion of the variability in the growth of Sitka spruce. Examples of this relationship are provided in Figures 1 and 2 where linear regressions of seedling height vs. ground elevation were done for two transects across Skeena Island 002. Small gains or losses in elevation can have a substantial effect on the growth of the spruce.

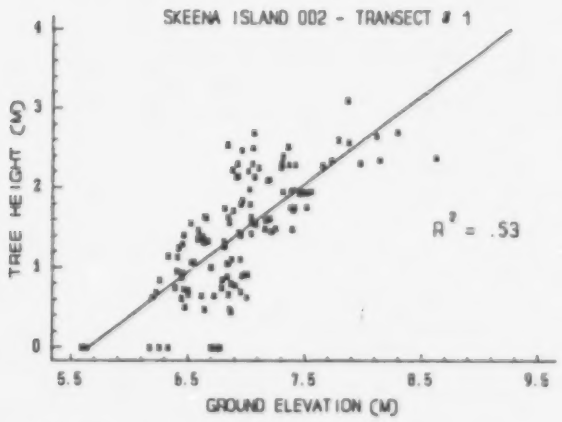

FIGURE 1. Linear regression – Transect # 1

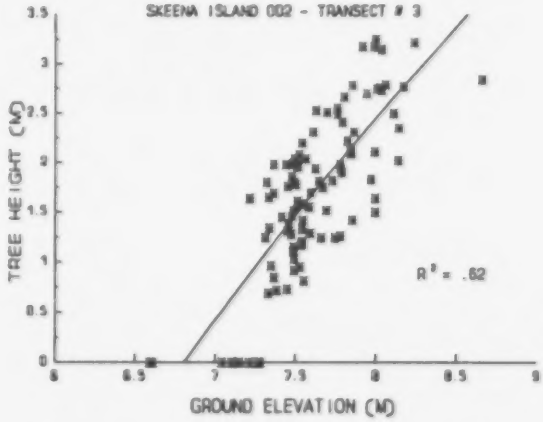

FIGURE 2. Linear regression – Transect # 3

Certain topographical and morphological features of the floodplain were identified as being unfavourable for the establishment and growth of Sitka spruce. Using 1:10 000 aerial photographs and a five-category frequency/duration classification, the user can identify site-specific flooding potential. The morphological and topographical descriptions of each class are included, along with the potential for Sitka spruce to grow under the existing flood hazard (Table 1).

TABLE 1. Definition of the five flood hazard classes

	Class I
Frequency	- Flooded not more than once a year.
Duration	- If flooded at all, duration is short, a few hours to half a day.
Implications	- The short duration flooding has no detrimental effect on tree growth.
Topography/ geomorphology	- High ground.
	Class II
Frequency	- Floods annually, usually once in the spring and once in the fall to a depth of 30-90 cm.
Duration	- Short, several hours to 1-2 days.
Implications	- Growth is not optimum, but is good.
Topography/ geomorphology	- High ground located between Class III and I. On aerial photos it is difficult to distinguish between I and II. Because both are safe classes, however, this has little consequence.
	Class III
Frequency	- Floods several times a year with mean annual high flows.
Duration	- Flooding usually occurs twice or three times per year for a total of 10-15 days, longer for higher peak flows. Note the shorter duration differentiates it from class IV.
Implications	- Growth of Sitka spruce is less than ideal, but can be acceptable. Survival can vary, depending on extent of flooding the year the seedlings are planted.
Topography/ geomorphology	- Same elevation as IV but sites are not confined. The most important characteristic is the "open" configuration.
	Class IV
Frequency	- Floods several times a year with mean annual high flows.
Duration	- Flooding occurs usually twice or three times a year for a total of 20-25 days, longer for higher peak flows.
Implications	- Growth rates of spruce seedlings are reduced; establishment is often not successful; cottonwood may be preferred.
Topography/ geomorphology	- Located immediately above class V or in moderate depressions that are "closed" to free drainage. Although these sites are at the same elevation as class III, the "closed" characteristic increases duration of flooding and consequently affects growth and establishment of planted seedlings.
	Class V
Frequency	- Floods at a wide range of flows, several times a year for extended periods.
Duration	- Several long duration flooding episodes each year. Total number of flooded days a year can exceed 30-40.
Implications	- No hope for Sitka spruce seedlings. Should be classed as non-commercial (NCC).
Topography/ geomorphology	- Located in the lowest elevations at the bottom of "closed" or "open" depressions.

Floodplain Suitability For Silviculture Investment

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INTRODUCTION

Prudent silviculture planning on a floodplain requires answers to two basic questions: 1) Is a particular land area likely to erode away over the next half century? and, 2) If the land is stable, what are the flood characteristics of the land area? These are difficult questions to answer because floodplains are inherently unstable. Their development depends on lateral channel migration involving erosion and deposition, and flooding. The individual features that make up the floodplain have a wide range of stabilities. Some features are stable over forest management time scales (e.g., terraces) while others are highly unstable over similar time periods (e.g., active channel zones). For these reasons, it is economically wise to determine how stable an area is before making silvicultural investments. Operationally, it is critical that the longevity of a site be determined before time and money are spent in areas that will not withstand erosion or floods.

STUDY LOCATION

The Skeena River floodplain between Telegraph Point and Terrace is approximately 75 km in length and 2.5 km in mean width. Islands are prevalent and range in size up to 300 ha. Historically, these islands have undergone substantial change. The lower Skeena River floodplain is also one of the most productive ecosystems for tree growth in the Coastal Western Hemlock Zone (CWHf) of the Prince Rupert Forest Region. However, the re-establishment of commercial tree species on these alluvial sites after logging is complicated by the invasion of various brush species. This problem, combined with the unstable nature of the floodplain, makes planning crucial in determining the feasibility of silviculture investments in certain areas.

The objectives of the study were:

1. to document the history of island development of the lower Skeena River over the past 45 years;
2. to evaluate island longevity by determining the rate of channel movement; and
3. to develop a classification scheme that identifies relatively stable areas suitable for silvicultural investment.

METHODS

The floodplain stability evaluation was based on chronological sequences of planimetrically correct maps. Overlaying the maps enabled the identification and quantification of areas eroding or depositing over the time period. A total of five air photograph series, spanning 45 years, were used.

RESULTS AND DISCUSSION

The calculated erosion and deposition rates, in addition to other factors such as sediment sources (tributaries, streams, and eroding islands upstream), channel pattern, man-made influence (road and rail construction), and valley wall-floodplain interactions were combined and used to generate a series of large scale maps (1:20 000). These describe erosion and deposition over the last 45 years and provide an interpretive summary of island stability. The maps presented at the poster session are based on the conditions prescribed in Tables 1 and 2.

TABLE 1. Description of erosion and deposition zones

Zone	Description
I	Areas without measurable erosion or deposition over the 45-year study period (1940-1986).
II	Areas of continual deposition over the study period: 0.75 ha/yr in total. These usually consist of many small zones (<0.125 ha/yr) and no large single zones.
III	Areas of little erosion or little deposition. Erosion or deposition does not exceed 0.75 ha/yr in total. Consists of many small zones (<0.125 ha/yr) and no large single zones.
IV	Areas of erosion and deposition, erosion and deposition exceed 0.75 ha/yr.
V	Large areas of erosion. Erosion exceeds 0.75 ha/yr and usually consists of many large areas.

TABLE 2. Summary of island stability classes

Class	Description
A	Islands appear stable or growing. Suitable for silvicultural investment. May incorporate stability zones I,II,III. May include open water.
B	Both erosion and deposition since 1940, or transition between A and C. Make silviculture investments only after careful on-site investigation. Primarily zone IV, but can include I,II,III, water, and back channels.
C	Areas of erosion or transport (open water) or areas that are historically stable but threatened by possible future erosion. Sites not suitable for silviculture investment. Primarily zone V and open water, but may include I, III, IV, and, though rarely, II.

These stability and interpretative maps combine all of the available geomorphic and hydrologic information on the Skeena River to allow identification of the most suitable and safest locations for silviculture investment. The maps are currently being used by Forest Service and industry staff in the North Coast and Kalum Forest Districts.

POSTERS

Natural Regeneration

Natural Regeneration of White Spruce on an Upland Site in Interior Alaska

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Adequate natural regeneration of white spruce following harvesting of upland sites in interior Alaska is uncommon. Seed availability and seedbed conditions seem to be the critical factors limiting rapid regeneration on these sites. We followed white spruce regeneration and secondary succession of the associated vegetation type on an upland site near Fairbanks, Alaska, over a 13-year period following forest harvesting. We tried to maximize the probability of good spruce regeneration through the use of conservative regeneration cuts (small clearcuts and shelterwoods) and site preparation.

The study was conducted on a gently sloping (5-25%), southwest-facing site near Fairbanks, Alaska (latitude 64°51' N, longitude 148°44' W), in the Bonanza Creek Experimental Forest. Mean elevation is about 240 m above sea level. Soil is silt loam in texture and derived from loess parent material. The dominant plant community was *Picea glauca/Viburnum edule/Equisetum arvense/Hylocomium splendens.* The stand contained a volume of 245 m^3/ha, density was 494 trees per hectare and basal area 23 m^2/ha. White spruce made up 90% of the volume. Average diameter was 28 cm and site index (100 year base age) was 26. Average tree age was 160 years. Paper birch, aspen, and balsam poplar were also present in the stand.

The study consisted of three 1- to 2-ha clearcuts and three 2- to 3-ha shelterwoods. Residual shelterwood density was 100 trees per hectare and basal area 9.2 m^2/ha. Units were harvested in the summer of 1972. Site preparation (scalping) was done with a standard blade mounted on a crawler tractor. It was completed in early October 1972. Scalped seedbeds were about 2 m wide and 2-3 m long; they were uniformly distributed at a spacing of about 4 x 4 m.

White spruce germination and 1st-year survival were studied on transects located on the scalped seedbeds. Seedling survival and growth, and changes in cover and presence of associated vegetation were followed on 20 paired plots (scalped and unscalped surfaces) in each of the six study units. Observations were made 1, 3, 5, and 13 years after harvesting.

A very good seed crop in 1972 provided about 306 filled seeds per square metre in the shelterwoods; the minimum filled seed density observed in the clearcuts was 200 per square metre. Virtually all spruce regeneration present on the site 13 years after harvesting resulted from this seed crop. In 1975, 4 years after harvesting, seed production similar to that in 1972 occurred, but few germinants appeared as a result of this seed crop, indicating that seedbed receptivity had dropped to near zero on scalped surfaces four growing seasons after site preparation.

Stocking (based on percent of square metres with one or more seedlings) and density of white spruce seedlings were significantly greater on scalped areas as compared to unscalped seedbeds; there were no significant differences in stocking and density between clearcuts and shelterwoods. Stocking on scalped surfaces exceeded 95%. On the untreated surfaces it was lower, 60%, but still surprisingly high based on past experience with unscarified surfaces in Alaska and elsewhere in the boreal forest. Seedling height and diameter after 13 years were not significantly affected by site preparation treatment, but seedlings were significantly smaller in shelterwoods than in the clearcuts.

General patterns of secondary succession were very different on scalped surfaces than on unscalped surfaces. Broadleaved trees (aspen and paper birch) and tall shrubs (alder and various willows) predominated on the scalped surfaces, having regenerated primarily from seed. On the untreated surfaces, herbaceous species present before harvesting tended to predominate. Two species not present prior to harvest, *Rubus idaeus* and *Geranium bicknellii*, were common after harvest and originated from seed present in the organic layers and surface mineral soil. Both species were more common on scalped seedbeds.

In summary, we believe that the exceptionally good spruce regeneration observed in this study was due to the combined effects of small harvesting unit size, site preparation, and a very good seed year. The composition of the associated vegetation on the scalped mineral soil surfaces was markedly different from that on the unscalped, mostly organic surfaces. An unexpected result of the study was that relatively good spruce regeneration was also observed on unscalped surfaces, suggesting that our knowledge of the relationship between organic surfaces and white spruce is incomplete.

COMPUTER TOOLS

The Fire Effects Information System: An Aid to Wildland Fire Management

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The Fire Effects Information System (FEIS), a "new generation" knowledge management tool, is designed to store and provide easy user access to state-of-the knowledge information on the effects of fire and general ecology of plant species and communities. System software was developed in a co-operative effort between the University of Montana Computer Science Department and the fire effects research unit of the USDA Forest Service's Intermountain Research Station.

Information is stored as text in the FEIS knowledge base and can be viewed as paragraphs on a screen. The system is menu-driven and requires only minimal experience with a computer to operate. The information is organized and accessed by categories. Information on plant species, plant communities and wildlife species is available.

Using a computerized system simplifies information updating. It also permits wider access to and greater consistency in information transferred from researchers to managers. When implemented, the system will be accessible to anyone with computer communication capabilities.

FEIS has the potential to "capture" useful information that may not be published in the generally available literature. Local studies and rules of thumb used by experienced managers in their fire prescriptions can quickly be made accessible to a broad audience once the information is included in the system.

The system's flexibility, logical organization, and ability to handle large amounts of complex information are the result of applying artificial intelligence programming techniques. FEIS contains information on over 240 plant species, many of which are species which may compete with conifers in the Pacific Northwest. Current plans are to increase the number of coniferous forest plants and communities represented in the system so that information available on coastal and Rocky Mountain species should expand rapidly in the near future.

During early development of the program, the prototype system was demonstrated at several dozen field locations in Arizona, Idaho, Nevada, Oregon, South Dakota and Utah. The participants listed the following potential uses of FEIS:

- prescribed fire plans
- fire rehabilitation plans
- escaped fire analysis
- land use plans
- exotic species control plans
- environmental assessments and impact statements
- vegetation management plans (range, wildlife habitat and silvicultural prescriptions)

- training programs
- research facilitation

The prototype system is now being tested by managers in the US Forest Service, Bureau of Land Management, and the National Park Service. Full implemetation is expected within the next 2-3 years.

Number of Plant Species and Life Forms by Ecosystem

(as of 13 October 1989)

Ecosystem	Trees	Shrubs	Graminoids	Forbs	Total
Forest & Woodland Ecosystems					
White-red-jack pine	2	1	-	-	3
Spruce-fir	4	2	-	-	6
Longleaf-slash pine	-	-	-	-	0
Loblolly-shortleaf pine	-	-	1	-	1
Oak-pine	2	-	-	-	2
Oak-hickory	10	9	15	5	39
Oak-gum-cypress	3	-	1	-	4
Elm-ash-cottonwood	12	18	26	3	59
Maple-beech-birch	7	2	1	-	10
Aspen-birch	8	-	2	-	10
Douglas-fir	25	29	30	8	91
Ponderosa pine	38	51	52	12	153
Western white pine	6	4	-	-	10
Fir-spruce	22	24	25	7	78
Hemlock-Sitka spruce	6	6	-	-	12
Larch	4	3	-	-	7
Lodgepole pine	17	11	3	1	32
Redwood	6	2	-	-	10
Western hardwoods	21	14	4	2	41
Shrubland Ecosystems					
Sagebrush	26	61	52	15	154
Desert shrub	11	48	32	7	98
Shinnery	-	4	3	1	8
Texas savanna	2	1	9	1	13
Southwestern shrubsteppe	1	4	8	2	15
Chaparral-mountain shrub	27	52	48	6	133
Pinyon-juniper	28	56	51	12	147
Grassland Ecosystems					
Mountain grasslands	13	39	45	11	108
Mountain meadows	-	-	-	1	1
Plains grasslands	17	29	48	10	104
Prairie	10	15	30	5	60
Desert grasslands	7	36	27	6	76
Wet grasslands	2	-	3	-	5
Annual grasslands	2	-	1	-	3
Alpine Ecosystems					
Alpine	4	7	6	3	20

A Free-growing Assessment System

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With the increasing size of Canadian reforestation programs, keeping track of the regeneration status of many sites, often with large silviculture expenditures, becomes difficult. Determining the final success of the regeneration phase and making final treatment decisions on brush control are both legal and silvicultural necessities. As well, the free-growing assessment is the initial point at which stand composition, density, distribution, and growth potential can be described for growth and yield estimation. For these reasons, better methods of data collection, analysis, and storage for secondary use are needed to allow maximum usage of field-collected data.

A PROTOTYPE SYSTEM

To fulfill the criteria descibed above, a prototype system was developed. Prototypes are meant to serve as a proof of concept and act as an interface between software developers and users. In this case, the system developed was designed to demonstrate the concept of an integrated system that would include automating the field data collection, relaying data collected in the field directly into the analysis program, and linking the output of the analysis with a geographic information system for data base update and map display. By automating this data transfer, many time-consuming steps should be removed and a better management information system produced.

THE FREE-GROWING ASSESSMENT SYSTEM

The system uses a Husky Hunter field portable data collector with a series of designed screens for data entry. The Hunter internally formats the field data into records describing crop tree species and growth, information on competing vegetation, and a header file describing the area surveyed for administrative purposes. The data are transferred directly off the Hunter to a personal computer where the data analysis program is stored. The input requirements of the analysis program match the output from the Hunter exactly. The analysis routine summarizes the stocking of crop trees, assesses the proportion that are free-growing, summarizes the major competing vegetation and its growth rate, and provides height over age data for the free-growing trees. The system also calculates (x,y) co-ordinates for each field plot and carries out a spatial analysis to determine whether stocking and competition problems are evenly or unevenly distributed. The output from this analysis package produces a file that is used by the B.C. Ministry of Forests GIS system. Written in PAMAP software, this program prompts the user to load a diskette for the mapsheet concerned. Then, using the plot co-ordinates, the stocking data are plotted within the opening concerned and the silviculture history layers in the GIS are updated. The map can then be zoomed, a legend added, and a hard copy printed.

A FIELD TEST OF THE SYSTEM

Four large clearcut blocks in the Squamish Forest District were surveyed with the system in October 1988. Compared with manual data collection, the field survey took 3 times as long to complete. The reasons for the extra time were contractor unfamiliarity with the system, some bugs in the software

programs, and the extra measurements taken by the free-growing assessment system compared with the current field survey system. However, the analysis from the prototype system was far more detailed than both the conventional survey system and automatic map production. Whether better familiarity of survey contractors with Husky Hunter or other dataloggers will reduce this time differential will have to be seen in future tests.

CONCLUSION

With the planned expansion of GIS coverage to 90% of Canada's forest land, users will be searching for applications of this software. One of the primary goals will be to make forest management decision-making better informed and more efficient. Development of packages such as the free-growing assessment system gives users some insight into the potential routes that can be taken in system design.

An Overview of ZELIG, a Family of Individual-Based Gap Models Simulating Forest Succession

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ZELIG is the current version of FORET (Shugart and West 1977; Shugart 1984), a widely applied simulation model of the population dynamics of multi-species, uneven-aged forests. These models have a record of successfully describing compositional changes in dominant vegetation over time and over strong physical gradients in space, using a minimum of site characteristics and simple natural history features of the plant species. Gap models such as FORET have been especially successful in describing successional development, equilibrial (climax) composition, and stem size class distributions found in forests naturally maintained by single tree replacement processes. Gap models are appropriate for describing vegetation dynamics when dominance is achieved through superior growth (site-species matching) and after release from competition. Disturbances such as fire, herbivory, thinning and harvest can be applied as external constraints at specified times or stages, although ZELIG is currently not designed to deal with stand management questions. The flexible framework in which ZELIG formulates demography and growth have made it useful for examining the determinants of vegetation pattern (Huston and Smith 1987; Smith and Urban 1988) and for projecting vegetation response to climate change (Urban and Shugart 1989).

Gap model formulation, developed originally by Botkin *et al.* (1972), revolves principally around the simple bookkeeping of the birth, growth, and death of individual trees simulated in several replicated plots on an annual time step. Growth of individuals is deterministic, with optimal growth (a sigmoid function of age) scaled down according to resource availability in each plot. However, the species and sizes of established seedlings and tree mortality are random. Probability thresholds are determined by maximum age of the tree, or the period of time it has undergone suppressed growth. This generates plot-to-plot variability, so that stand or landscape level trends are described by the mean and variance of results across all plots (20-50 replicates are typically required for stable behaviour). The option to have plots serve not as random replicates but as contiguous cells (influencing each other through shading, seed rain, and the probability of disturbance) allows ZELIG to address the generation of landscape pattern (Smith and Urban 1988).

The size of plot used on the simulation is scaled to represent the zone of influence of a single dominant tree. This scaling is critical, because all plants growing in the plot are considered to belong to the same competitive neighbourhood, responding to and affecting the same pool of resources. Plant positions in a simulation plot are not spatially explicit in the horizontal plane, but are explicit as strata of foliage in the vertical plane. Light attenuation through the plot's canopy is predicted from cumulative leaf area index above each stratum using the Beer-Lambert Law, with potential growth of each tree constrained according to the amount of light it can intercept. Actual growth responses (expressed as an annual increment in stem diameter) vary according to estimates of shade tolerance of the species, and can also be constrained by soil moisture availability, site fertility and temperature (growing degree-days). Tree height and total foliage area are recalculated annually as functions of stem diameter. ZELIG's modular structure allows local calibration by substitution of empirical information or alternative sub-models, as available, for optimal growth, environmental responses (tolerances), and site attributes such as soil moisture balance. One of its strengths, however, is the ability to simulate basic species dynamics

without elaborate calibration. Input data consist of site characteristics (estimated using standard site diagnosis procedures, such as Klinka *et al.* 1984) and basic species attributes at the level of detail presented in Fowells (1965) (Table 1).

TABLE 1. Sample DAT file for ZELIG.ZIP, giving run parameters, site characteristics, and species attributes

ZELIG version ZIP.1 (Demo for VegMan Workshop)

1[a]	0[b]	20[c]	08[d]	200[e]	10[f]	200[g]	200[h]

UBC Knapp Forest, Haney[i]

DROUGHT-DAYS: 0.10[j] SOIL FERTILITY: 0.80[k]

l	m	n	o	p	q	r	s	t
ABAM	600	200	5500	170	1	2	2	20
ALRU	150	150	4000	250	5	2	1	80
PISI	750	400	9000	210	4	2	1	30
PIMO	600	200	6000	185	3	3	1	20
POTR	250	200	4500	225	5	2	1	100
PSME	999	425	8500	205	3	4	2	50
THPL	999	350	6000	150	3	2	1	35
TSHE	500	225	8000	160	2	3	3	70

Run Parameters:

a mode independent (1) or interacting (0) plots

b starting with bare ground (0) or data file (1) of starting trees (list giving DBH and species of each starting tree)

c number of replicate plots

d number of species

e number of years

f print interval, years

g punch interval, years

h profile interval, years

Site Characteristics:

i site or run label.

j proportion of the growing season to experience moisture stress, 0 to 0.5

k site fertility, 0.4 to 0.9

Species Attributes:

l species code (generally the first two letters of the genus and species; these species are *Abies amabilis*, *Alnus rubra*, *Picea sitchensis*, *Pinus monticola*, *Populus trichocarpa*, *Pseudotsuga menziesii*, *Thuja plicata*, and *Tsuga heterophylla*)

m maximum age (achieved by 1% of adults, ideal conditions)

n maximum dbh, cm

o maximum height, cm

p growth rate, the "G" parameter as defined in Shugart 1984; estimated separately using the program GEST

q shade tolerance, (1 = very tolerant, 5 = very intolerant)

r drought tolerance, proportion of growing season that can be survived under moisture stress, times 10; typically 1 (moisture demanding) to 5 (very drought tolerant)

s nutrient response (1 = demanding, 3 = stress tolerant)

t inseeding rate, number of seedlings to emerge per plot (500 m^2) per year

There are several versions of ZELIG, each with different enhancements and capabilities. ZELIG.FOREST is a generic model of forest dynamics, with soil moisture and temperature constraints, foliage profiles, and options for plot interaction. It is being used as a standard tool for comparing vegetation patterns at several forested sites in the United States' Long Term Ecological Research (LTER) network. ZELIG.FOREST is written in Fortran-77 and is currently executed only as a mainframe program.

ZELIG.ZIP is a more portable version, simplified to run on IBM-PC compatible microcomputers. This program simulates light competition, with simple constraints on site fertility and the proportion of drought days in the growing season. Like the mainframe model, however, it also generates output files describing basal area by species over time (a TRACER file), stem tallies by species and size class at specified intervals (a PRINT file), and a description of the foliage profile of each plot (a PROFILE file). Figure 1 is a plot of the TRACER file for a 200-year simulation at a coastal lowland site in southern British Columbia (UBC's Malcolm Knapp Forest at Haney), using the input file described in Table 1. Figure 2 shows a sample PRINT file (stem tally projected for Year 100) generated by a ZELIG.ZIP execution for a boreal mixedwood scenario.

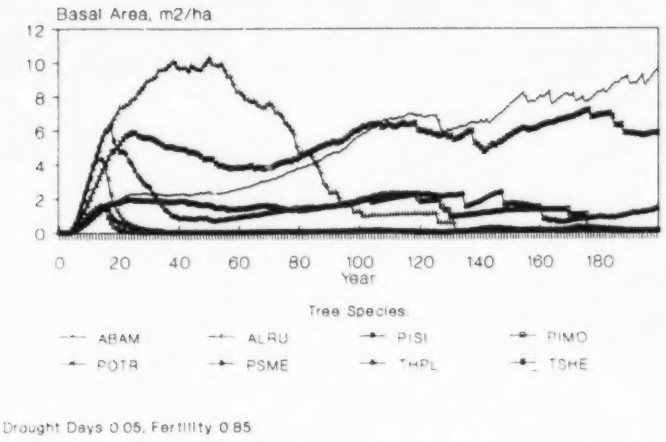

FIGURE 1. Sample plot of ZELIG.ZIP TRX file for coastal forest succession at a good site, UBC Knapp Forest, Haney, B.C.

SIMULATION YEAR: 100

AGGREGATE STATICS (MEAN OVER 20 500 M^2 PLOTS)

SPP:	DBH	DISTRIBUTION	(< 2.5 THEN BY 10 CM):										DENS.	B.A.	RIV200
BEPA	28	18	0	0	0	0	0	0	0	0	0	0	18	.02	4.38
POBA	30	28	0	0	0	0	0	0	0	0	0	0	28	.03	6.84
POTE	17	19	0	0	2	2	0	4	0	0	0	0	27	1.75	35.44
PIGL	87	116	3	16	2	0	0	0	0	0	0	0	137	1.17	50.48
PIMA	8	0	0	0	0	0	0	0	0	0	0	0	0	.00	.00
PICO	11	12	0	0	0	0	0	0	0	0	0	0	12	.01	2.86
SUM	181	193	3	16	4	2	0	4	0	0	0	0	222	2.97	100.00

STAND ESTIMATES:

DBH DISTRIBUTION (STEMS/HA):

724.0 772.0 12.0 64.0 16.0 8.0 .016 .0 .0 .0 .0 .0

DENSITY: 888.00/HA

BASAL AREA: 11.897 SQM/HA MEAN DBH: 7.58 CM

TOTAL WOODY BIOMASS: 75.151 T/HA LEAF AREA INDEX: 3.893

FIGURE 2. Sample of the PRINT file generated by ZELIG.ZIP for a boreal mixed wood scenario, NE B.C.

Of greater interest to vegetation management is the multiple growth form version, ZELIG.MGF, currently running only on mainframes. This model (Burton and Urban 1989) also simulates the growth of shrubs and herbs, using the principles that competition is principally for light (although moisture and fertility can constrain some species more than others); all plants affect light availability and individuals grow in response to their interception of light; and demography is a stochastic process of recruitment (from seed and vegetative sprouts) and mortality (both age-dependent and stress-dependent). Because herbs and shrubs grow much differently than trees, however, reformulation of several central algorithms was required. In addition to the input parameters, ZELIG.MGF requires description of each species' (1) woodiness, (2) foliage profile, (3) average number of stems, (4) monocarpic behaviour, and (5) vegetative reproduction. Foliage profiles (Figure 3) were found to be especially important, as was vegetative reproduction. Options exist for output as time traces of basal area, biomass, or cover. Figure 4 shows a sample prediction for post-logging succession at the UBC Knapp Forest, executed as an 18 species run in 50 m^2 plots, but summarized in seven plant groups.

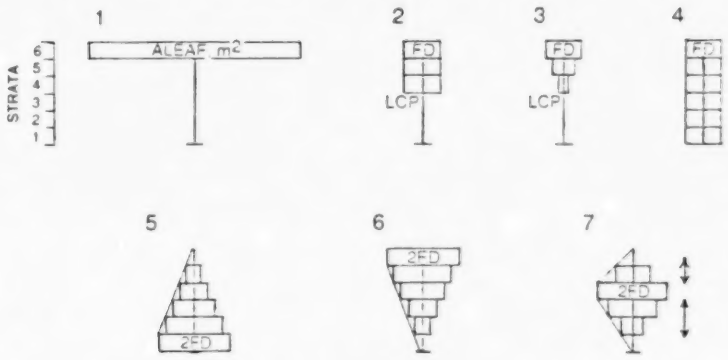

FIGURE 3. Foliage profiles simulated in ZELIG.MGF.

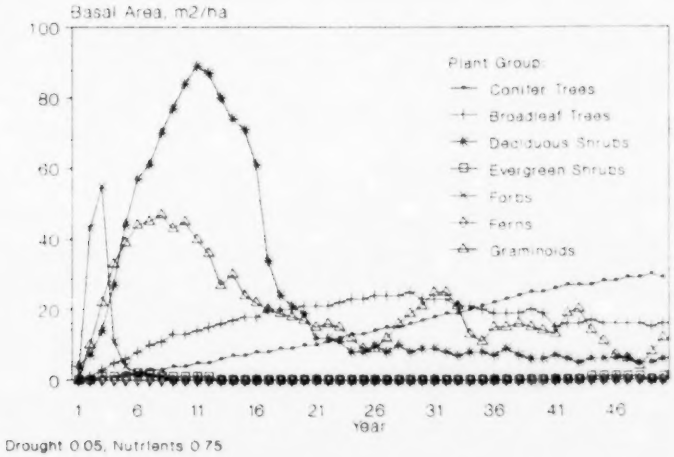

FIGURE 4. Simulation of post-logging succession, ZELIG.MGF8, UBC Knapp Forest.

Future work with ZELIG is focusing on (1) the development of VEGOMAT (Smith *et al.* 1989), a framework for the simulation of herb and shrub growth within, (2) landscape-level considerations of diversity, wildlife habitat and hydrology, (3) improved parameter estimation for dominant species in conifer-dominated ecosystems, (4) the compilation of data for verifying model predictions, and (5) building in management options for the testing of alternative silvicultural practices.

LITERATURE CITED

Botkin, D.B., J.F. Janak, and J.R. Wallis. 1972. Some ecological consequences of a computer model of forest growth. J. Ecology 60:849-872.

Burton, P.J., and D.L. Urban. 1989. Enhanced simulation of early secondary succession by incorporating multiple growth/form interaction and dispersal. Studies in plant ecology (Svenska Växtgeografiska Sällskapet, Uppsala) 18:47-49.

Fowells, H.A. (editor). 1965. Silvics of forest trees of the United States. U.S. Dep. Agric. Handb. No. 271. 762 p.

Huston, M. and T.M. Smith. 1987. Plant succession: life history and competition. The Am. Naturalist 130:168-198.

Klinka, K., R.N. Green, P.J. Courtin, and F.C. Nuszdorfer. 1984. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region. B.C. Min. For., Victoria, B.C., Land Manage. Rep. No. 26. 180 p.

Shugart, H.H. 1984. A theory of forest dynamics: the ecological implications of forest succession models. Springer-Verlag, New York, N.Y. 278 p.

Shugart, H.H., and D.C. West. 1977. Development of an Appalachian deciduous forest succession model and its application to assessment of the impact of the chestnut blight. J. Environ. Manage. 5:161-179.

Smith, T.M., and D.L. Urban. 1988. Scale and resolution of forest structural pattern. Vegetatio 74:143-150.

Smith, T.M., H.H. Shugart, D.L. Urban, W.K. Lauenroth, D.P. Coffin, and T.B. Kirchner. 1989. Modeling vegetation across biomes: forest-grassland transition. Studies in plant ecology (Svenska Växtgeografiska Sällskapet, Uppsala) 18:240-241.

Urban, D.L. and H.H. Shugart. 1989. Forest response to climatic change: a simulation study for southeastern forests. *In* Potential effects of global climate change on the United States. J.B. Smith and D.A. Tirpak (editors). Document EPA-230-05-89-054. U.S. Environ. Protect. Agen., Washington, D.C.

COMB: A Computerized Bibliography on the Ecology, Utilization, and Management of Several Species that Compete with Conifers

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SUMMARY

COMB is a computerized bibliography that includes citations and abstracts of published references dealing with the ecology, competitive status, utilization, and management of several plant species which compete with conifer seedlings in British Columbia. This bibliography was developed to simplify the acquisition of reference materials by operational, research, and extension staff.

The data base can be searched for references dealing with specific topics, and citations and abstracts can be displayed on screen or printed. Users of the current version of the computerized bibliography must have an IBM-PC or compatible microcomputer and dBASE III PLUS.[1] The COMB package includes programs for use with dBASE III PLUS, which simplify these searches.

The species presently included in the data base are:

Alnus viridis ssp. *sinuata*	Sitka alder
Athyrium filix-femina	lady fern
Betula papyrifera	paper birch
Calamagrostis rubescens	pinegrass
Cornus sericea	red-osier dogwood
Epilobium angustifolium	fireweed
Lonicera involucrata	black twinberry
Menziesia ferruginea	false azalea
Pteridium aquilinum	bracken
Rhododendron albiflorum	white-flowered rhododendron
Rubus idaeus	raspberry
Rubus parviflorus	thimbleberry
Sambucus spp.	elderberry species

Species currently being added to the bibliography include:

Acer circinatum	vine maple
Acer glabrum	Douglas maple
Acer macrophyllum	bigleaf maple

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[1] dBASE III PLUS is a registered trademark of Ashton-Tate.

Alnus rubra	red alder
Corylus cornuta	beaked hazelnut
Gaultheria shallon	salal
Oplopanax horridus	devil's club
Polystichum munitum	sword fern
Rubus spectabilis	salmonberry
Vaccinium spp.	huckleberries and blueberries

Copies of references listed in the bibliography that are shorter than 20 pages in length are on file in the UBC INFORMS Library and at the B.C. Ministry of Forests, Research Branch, Victoria.

In early 1990, the COMB package will be expanded to include all software required for its use. In addition, data base files will be made available for use with PRO-CITE[2] software.

Support for development of the COMB computerized bibliography has been provided by the Canada-British Columbia Forest Resources Development Agreement.

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2 PRO-CITE is a registered trademark of Personal Bibliographic Software Inc.
Reference to specific software does not represent an endorsement of this product by the Ministry of Forests or Forestry Canada.

Reforestation Information Bank

Berken Feddersen

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The Reforestation Information Bank (RIB) is designed to be used as an electronic reference system by which any individual, agency, or organization can have access to the latest developments in backlog reforestation in northern and coastal British Columbia. This microcomputer-based system is menu driven. The main menu organizes the information into categories, each of which has submenus with keywords. It contains results from industrial, federal, and provincial operational and research trials. Information provided by the data base includes:

- a contact person, agency and telephone number
- trial objectives
- summaries of results
- citations for each trial

Searches of the data base may be conducted using the following criteria:

- geographic location
- biogeoclimatic zones
- species
- silviculture activities

RIB is designed to provide easy access to active and recently completed operational and research trials. It facilitates rapid and efficient transfer of information from the researcher to the field forester.

Herbicide/Wildlife Forage Data Directory

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The purpose of this system is to consolidate information pertaining to the response of some important wildlife forage species to various herbicide treatments.

The data is stored in such a manner that it may be searched and manipulated using DATAtrieve. DATAtrieve is an interactive language and report-writing tool available on British Columbia Systems Corporation's VAX system.

The directory was compiled from selected herbicide trials and each entry includes the following information: the phenological stage of the species, the trial location, the chemical name, the rate and method of application, and the results. Four chemicals are included: glyphosate, liquid hexazinone, 2,4-D amine, and triclopyr ester. There are three rate categories per chemical: individual; ≤ 1/2 the maximum Canadian label rate; >1/2 the maximum ≤ maximum Canadian registration rate. Five applications are used: dormant, early foliar, late foliar, late summer, and fall. Currently there are 35 forage species listed and a total of 1923 data bits.

For most of the forage species, there is limited information available for the 90 possible treatment combinations. Because widely varying methods and response measures are recorded, comparisons between trials are generally not statistically valid.

The potential to expand the data base is tremendous. The utility of the directory can only be improved by the addition of good quality data.

The objective nature of the data, in combination with the system's user-specified search and analysis abilities, makes the system an attractive resource for vegetation managers.

The Wildlife Branch is currently working on a model to evaluate herbicide impacts on forage resources. The data directory will provide a source for much of the information required for this work.

CLUMP: A Computer Model for Predicting Douglas-fir Yields in Association with Bigleaf Maple Sprout Clumps

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Bigleaf maple (*Acer macrophyllum* Pursh) sprouts vigorously following cutting or burning. Initial height growth rates range from 1.5 to 3 m/year, and the developing sprout clumps of bigleaf maple can compete with young Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), reducing the growth of crop trees and often causing substantial mortality. This species is common throughout western Oregon and Washington.

Typically, forest managers in the Pacific Northwest apply vegetation management treatments to eliminate or suppress bigleaf maple sprout clumps when they occur at high densities (>60/ha) in Douglas-fir plantations. However, when the sprout clumps occur in low densities (<20/ha) or scattered patches, their potential economic impact on a Douglas-fir plantation is not easily quantified. Thus, forest managers lack the critical information they need to make the appropriate decisions for treatment of bigleaf maple competition.

The CRAFTS vegetation management research co-operative at Oregon State University (OSU), has several research projects under way on bigleaf maple. These include a comparison of control treatments, a crown development model for 1- to 10-year-old sprout clumps, and a study to determine the size of gaps produced by bigleaf maple in 20- to 60-year-old stands of Douglas-fir. To integrate this information into a framework for treatment decision-making, CRAFTS is developing a stand growth simulation model.

The stand growth simulation model is called CLUMP, an acronym that stands for Competition Losses Using Maple Projections. A preliminary version of CLUMP has been developed, and it is now being refined. The model uses the following inputs to simulate stand growth for a rotation length of 50 years or more (Figure 1): Douglas-fir site index, current stand age, rotation length, initial average size and density per species, and final Douglas-fir density.

To describe the dynamics of the developing mixed species stand, the simulator uses a co-ordinate system to map locations of each Douglas-fir and bigleaf maple sprout clump on a 0.4 ha^2 unit of land. A Weibull probability density function is used to generate the initial height distribution of bigleaf maple clumps on the unit area, and the sprout clumps are randomly located throughout the Douglas-fir stand.

Potential height and crown width growth of individual Douglas-fir are predicted using Richard's equations based on site index. Overtopping cover from neighbouring bigleaf maple causes a proportionate reduction in Douglas-fir height and crown width increment. Bigleaf maple height and crown width growth are predicted using Richard's equations that were developed from data collected by CRAFTS co-operators and staff. The model causes individual Douglas-fir to die when they experience greater than 80% overtopping by neighbouring bigleaf maple for a period of 10 years.

At rotation age the volume of individual Douglas-fir is predicted from tree height, final density, and stand age using a regression equation based on output data from SPS[1]. Total Douglas-fir stand volume is calculated as the product of mean tree volume times final density, where Douglas-fir trees that have died have zero volume. This calculation assumes that, since mortality occurs randomly throughout the

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[1] Arney, J.D. 1985. SPS: stand projection system for mini- and micro-computers. J. For. 83(6): 378.

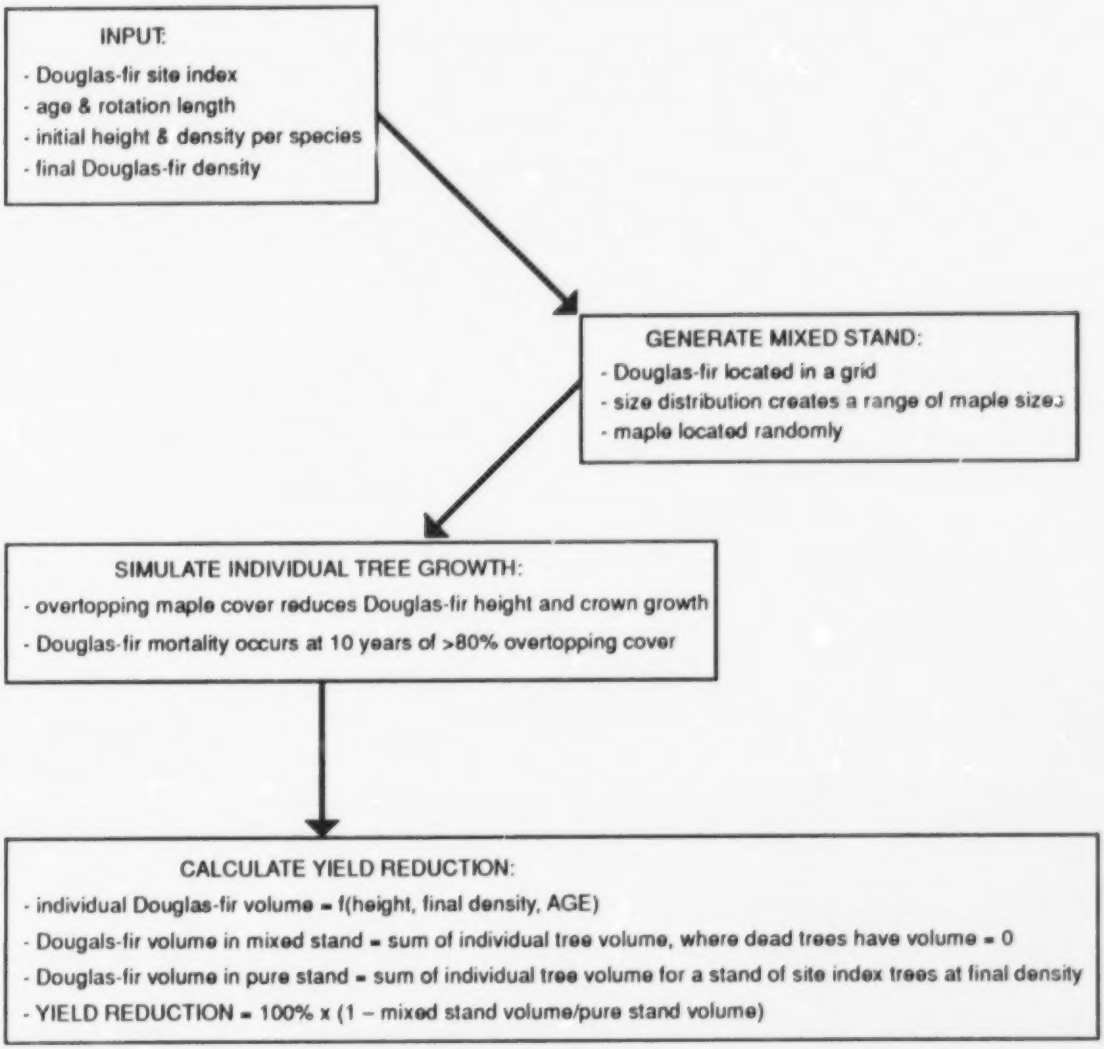
INPUT:
- Douglas-fir site index
- age & rotation length
- initial height & density per species
- final Douglas-fir density
GENERATE MIXED STAND:
- Douglas-fir located in a grid
- size distribution creates a range of maple sizes
- maple located randomly
SIMULATE INDIVIDUAL TREE GROWTH:
- overtopping maple cover reduces Douglas-fir height and crown growth
- Douglas-fir mortality occurs at 10 years of >80% overtopping cover
CALCULATE YIELD REDUCTION:
- individual Douglas-fir volume = f(height, final density, AGE)
- Dougals-fir volume in mixed stand = sum of individual tree volume, where dead trees have volume = 0
- Douglas-fir volume in pure stand = sum of individual tree volume for a stand of site index trees at final density
- YIELD REDUCTION = 100% x (1 – mixed stand volume/pure stand volume)

FIGURE 1. Flowchart for CLUMP, a stand growth simulation model for predicting the effects of bigleaf maple sprout clumps on Douglas-fir yield.

stand, mortality of individual trees translates to a proportionate loss of crop trees at final stand density. Yield reduction resulting from bigleaf maple competition is calculated as one minus the proportion of pure Douglas-fir yield attained by the mixed stand, where pure Douglas-fir yield equals the total volume of a stand composed of site index trees at the final density.

In future versions of CLUMP, yield from bigleaf maple will be included in the stand summary, and the economics of mixed versus pure stand management of Douglas-fir will be compared using cost/revenue discounting. When completed in 1990, CLUMP will be able to forecast the effects of several bigleaf maple control treatments on stand yields, thus making this model a comprehensive tool for determining the best management regimes for mixed Douglas-fir/bigleaf maple stands.

Operational Herbicide Monitoring in the Prince George Forest Region

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Currently, over 4000 ha are weeded annually in the Prince George Forest Region alone, with projections for increased activity (B.C. Ministry of Forests 1988). Although manual methods are possible in some cases, chemical weeding with glyphosate is the predominant treatment method used, due in part to its effectiveness at controlling several species.

Close involvement of the public and technical audit by various regulatory agencies has increased concommitantly with increased herbicide use. Demands for greater accountability in herbicide prescriptions imply that prescriptions require validation. Consequently, the need for developing and implementing an objective monitoring methodology capable of validating prescriptions has been paramount.

A monitoring system for objectively evaluating operational aerial glyphosate treatments, called O.H.M., was developed and field-tested in the Prince George Forest Region in 1988. Its overall objective is to generate response data suitable for developing and validating silvicultural prescriptions involving aerial herbicide application, assessing treatment options and developing cost/benefit analyses. Its specific objectives are to obtain response data from operational herbicide projects by monitoring crop tree growth response and treatment tolerance, herbicide efficacy on prescribed target vegetation, and treatment effects on wildlife forage; and to test and validate a prescription- setting system.

The O.H.M. system is intended to examine the range of stock types and plantation ages currently receiving herbicide prescriptions. Consequently, candidate spray sites are characterized by various site histories and ecological conditions. Both control and designated treatment portions are assessed immediately before, and in the years following treatment so that greater confidence can be gained in evaluating treatment effects. Installations are designed and maintained for evaluation of post-treatment response over a 10-year period.

In 1988, immediately before spraying, pre-treatment assessments were successfully completed at five installations representing a wide range of stock types, plantation ages, and ecological conditions. Post-treatment evaluations commenced the following year. Eight additional installations were established in 1989, expanding the previous range of conditions being monitored. These will be assessed for post-treatment response in 1990.

The O.H.M. addresses its first specific objective by emphasizing measurement of three stand components: crop trees, target vegetation, and wildlife forage. Each component requires a unique sampling strategy that is distinct in purpose, approach and sampling intensity. However, the sampling techniques are complementary and comprehensive, integrated in a standardized assessment format. Data are collected using one of three specific computer programs on a Husky Hunter field computer.

In each designated control and treatment area, 100 crop trees are intensively sampled with the use of a grid layout of 100 permanent sample points located at 10-m intervals. At each sample point, the nearest crop tree marks the centre of a 5-m^2 circular subplot within which crop tree characteristics are assessed using Regeneration Performance Assessment (RPA) software.

Target vegetation response is evaluated in 20 point-centered 5-m^2 circular subplots, systematically sampled from the 100 previously established sample points within each treated and control block. Target species characteristics are assessed using Weed Control Subplot Assessment (WCSA) software.

Two 200-m^2 circular macroplots are used for monitoring species composition and structure of the vegetation community under evaluation, and subsequent habitat change following herbicide treatment (B.C. Ministry of Environment and Ministry of Forests 1988). A non-standardized technique is also used to assess wildlife forage abundance (R. Lloyd, pers. comm., Consultant, Smithers, B.C. 1988) employing General Data Collector (GDC) software.

Treatment response within each installation is analyzed using an analysis of covariance or a student's t test. Replication of treatments is accommodated by comparing installations having similar ecologic conditions, provided their site histories, stock type, and plantation characteristics are comparable. Examination of typical treatment effects over a broader geographic area uses an analysis of variance of appropriately pooled data, and is particularly relevant to the prescription-setting and validation process.

The second specific objective employs the Brand-Janis free-growth prediction model (1986) to examine rates of growth between crop trees and competing vegetation. The model provides an index of free-growth, current and projected, against which the need for brushing and weeding may be evaluated by forest managers.

REFERENCES

Brand, D.G. and P.S. Janis. 1986. Regeneration performance survey system: system overview and user's manual. Petawawa National For. Inst., Internal Report Petawawa, Ont.

B.C. Ministry of Forests. 1988. Ministry of Forests and Lands Annual Report 1986-87. Victoria, B.C.

B.C. Ministry of Environment and Ministry of Forests. 1988. Procedures for environmental monitoring in range and wildlife habitat management - draft report. Victoria, B.C.

Fire Effects Expert System Project

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This project was a co-operative effort involving the Protection Branch of the Ministry of Forests, Forestry Canada, the U.B.C. Faculty of Commerce and Business Administration, and the Forest Economics and Policy Analysis Project. The major objectives were to investigate the feasibility of applying expert systems technology to prescribed burning decision-making and to develop a prototype for an expert system to predict the ecological effects of such prescribed burns.

Expert system technology is well suited to the prescribed burning field because of the qualitative nature of the decisions, the large number of potential solutions, the diversity of knowledge sources, and the relative scarcity of experts. However, there are problems such as uncertainty of knowledge and inherent complexity of the natural system and its reaction to prescribed fire.

To construct the expert system, five experts in the fire effects research field were interviewed and a conceptual model developed. Structured interviews then followed to elicit knowledge and determine the rules expressing the relationships between the factors. A prototype system was developed, built, and then reviewed by the experts.

A typical user of the system would be a forester or forest technician who is not necessarily an expert in the ecological effects of fire, but has the responsibility for planning and conducting prescribed burns. The expert system would be used as a means of developing the fire prescription for a burn block or, alternatively, as a gaming tool or training aid. It has the advantages of being consistent amongst all users and incorporating the most current knowledge. It can also be updated at any time.

The Fire Effects Expert System uses the limiting factor concept to compare various determinants of tree growth. Each growth limiting factor is rated on a numeric scale of 1 to 8, both pre-burn and post-burn. The expert system explains the reasoning used to determine the ratings. The output is an assessment of whether fire would be beneficial or detrimental in terms of each limiting factor.

The modules employed in the expert system are (1) fire effects, (2) fuel characteristics, (3) vegetation, (4) root rot, (5) soil nutrients, (6) soil temperature, (7) air temperature, (8) soil moisture, and (9) evaluation of limiting factors. Although the system at present only includes complete data for one ecosystem association in one biogeoclimatic subzone, the conceptual model could be applied provincially.

Typical input parameters required by the system include the stock type and the site's ecological classification, soil moisture regime, soil nutrient regime, aspect, slope, fuel flammability (species, loading, and distribution), duff depth, fire weather index, vegetation characteristics (species, cover, and height), presence and status of root rots, forest floor characteristics, microtopography, and macrotopography. Inputs are run through each of the nine modules.

A graphic display is provided for the limiting levels of the various growth factors (vegetation, root rot, nutrients, soil temperature, air temperature, and moisture) – both pre-burn and post-burn. If the assessment of probable prescribed fire impact is unacceptable to the user, the program can be rerun with a new prescription (based solely on changing the fire weather indices under which the burn will be carried out).

In the field of fire management decision support, the Protection Branch of the Ministry of Forests strives to provide up-to-date technical data and associated information through a series of interactive computer applications on a distributed network. This could serve as a suitable vehicle for incorporation of new tools in the form of expert systems.

The Fire Effects Expert System is currently being revised to run solely under "Turbo Prolog," and the internal models used will be documented, the expert system design explained, and a training package produced. It is anticipated that the system will be tested and evaluated in two Forest Regions in 1990.

FORCYTE and FORECAST: Ecosystem-level Management Models with Which to Examine the Yield, Economic, Energy and Wildlife Implications of Vegetation Management as a Component of Rotation-Length Silvicultural Systems

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Rotation-length stand management involves the manipulation of secondary succession over the stand cycle. Non-crop vegetation can play an important role in this successional cycle, a role which can vary from positive to negative. Non-crop plants can: reduce nutrient leaching or denitrification losses; provide symbiotically fixed nitrogen; reduce soil erosion losses; afford microclimatic protection to crop seedlings; protect seedlings from browsing damage; and provide both food and cover for desirable wildlife species. Conversely, non-crop vegetation can compete with crop seedlings for nutrients, water, and light; delay crop canopy closure; create unfavourable microclimatic conditions; and harbour species of wildlife that may damage or kill crop trees.

Management of non-crop vegetation can result in major gains in early tree growth and a rotation length improvement in volume and value. However, much of the gain may be lost over medium (60 yr) to long (100 yr) rotations if there are no intermediate harvests. In some cases, removal of such vegetation may adversely affect rotation length value and volume. For example, the removal of one non-crop species which is adversely affecting crop seedlings may permit another species to develop, which has even more negative effects on the crop trees. Investment in vegetation management should, therefore, be based on rotation-length evaluation of stand-level yield, economics, wildlife, and other considerations, as well as on the more traditional short-term "free-growing" evaluations.

Comprehensive rotation-length evaluation of vegetation management requires the use of ecosystem-level management simulation models that include production, yield, economics, energy, and wildlife-related predictions. Such models should represent the ecological role of all the plant life forms that are significant in the area in question, and should be capable of representing all silvicultural practices. The yield, economics, and other consequences of vegetation management cannot be evaluated independently. They must be considered as a component of a rotation-length system of silvicultural activities.

The ecosystem-level management simulation model FORCYTE-11 (FORest Nutrient Cycling and Yield Trend Evaluator)[1] gives foresters the opportunity to perform deterministic simulations of several vegetation management options within a framework of simulated rotation-length silvicultural systems. It

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[1] The development of FORCYTE was funded by Forestry Canada under the ENFOR program.

provides an economic and energy-use analysis, in addition to predictions of total production and yield, by species; of the site capitals of organic matter and nutrients; and of the soil fertility and biogeochemical budget.

FORECAST (FORestry and Environmental Change ASsessmenT) is a new model being developed at UBC. Borrowing heavily from the modeling strategy used in FORCYTE, it will have additional vegetation management simulation capabilities (mechanical site preparation, spot weeding and fertilization, moisture competition, improved representation of allelopathy, and climate-change effects). FORECAST will also include some stochastic simulations to improve its representation of the variability of early secondary succession, and the response of minor vegetation to tree stocking control.

FORCYTE-11 will soon be available for field evaluation through Forestry Canada, Edmonton. Anyone interested in establishing a co-operative field test of the model should contact Dr. M.J. Apps at Forestry Canada.

Salal Growth and Competition Model

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INTRODUCTION

Salal (*Gaultheria shallon* Pursh.) appears to be a competitor with forest crop trees during plantation establishment and, on drier sites, when thinning is conducted. Neither the degree of competition nor the long-term consequences to crop productivity are known. Consequently, the economic benefits of vegetation control cannot presently be assessed. A simple tool for evaluating the necessity of salal control and the long-term consequences of control measures would be an aid to managers.

The Salal Growth and Competition Model originated within the scope of FRDA Project 2.32 (Productivity, population dynamics, and competitive ability of salal - existing data). Data bases used in the completion of this project were primarily restricted to those collected by F.L. Bunnell and his graduate students (Bunnell and McCann, these proceedings). Incorporation of data from both industry and the B.C. Forest Service will permit further development and extension of the model. This effort is currently being supported by the Science Council of British Columbia.

MODEL DESCRIPTION

General

The model is written in Basic and intended for use on IBM compatible personal computers with graphics capability. Ease of use and portability of the model is provided through a user-friendly graphics simulation supervisor and compilation of the code into a stand-alone executable program. Model output is in the form of line and scatter plots of modeled variables versus time, or one variable versus another. Variable values and their associated iteration number are also available in tabular format. Output is available from the model in 1-year time steps.

Computational Steps

The model simulates stand characteristics (Figure 1) resulting from various site qualities and silvicultural treatments, via output generated by the simulation model TASS (Mitchell and Cameron 1985). Salal biomass per unit area is determined in two steps: 1) functional relationships developed by Vales (1986) relate salal above-ground biomass components to stand characteristics such as mean canopy completeness (e.g., Figure 1) and Reineke's stand density index (Reineke 1933); 2) estimates from Vales' equations provide a target biomass value against which salal always grows or declines (Figure 2). Salal biomass is used to determine a cost (e.g., nutrients) borne by the site to support the salal.

Weaknesses

All models have inherent weaknesses. Further development and extension of the model is aimed at addressing several current weaknesses. Specifically these are: 1) the model's estimates of mean crown completeness (MCC) and salal biomass in young stands (<35 years old) are extrapolations beyond the range of the data used to develop the relations; 2) the influence of site preparation (e.g., burns of different intensity) and thinning on competition by salal cannot be evaluated; 3) simulations are restricted to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands; and, most importantly, 4) the cost a site pays to support a particular biomass of salal is not expressed in terms of reduced productivity of crop trees.

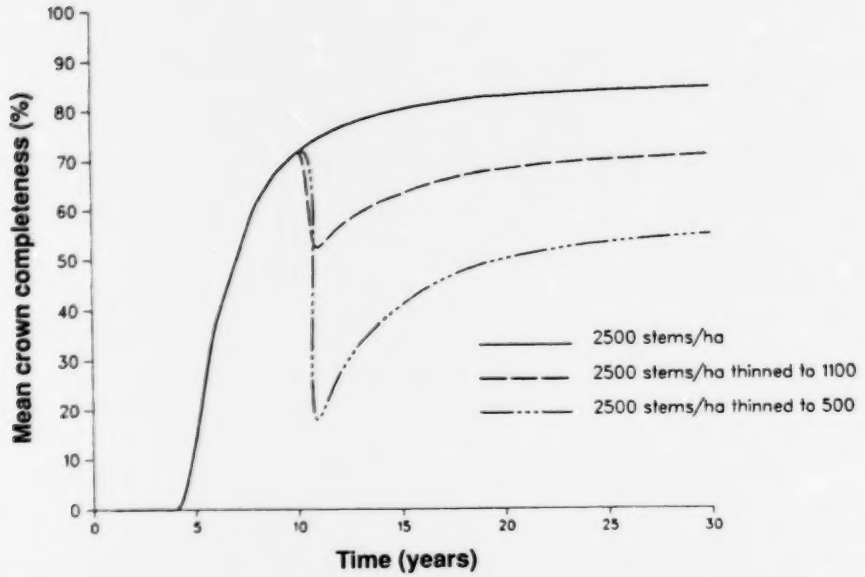

FIGURE 1. Mean crown completeness (MCC) of three modeled Douglas-fir stands subjected to different silvicultural treatments.

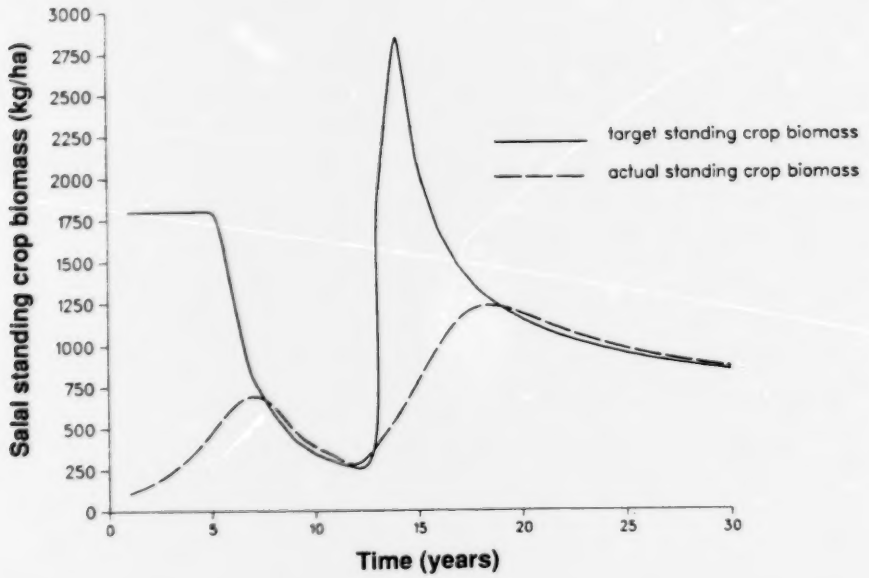

FIGURE 2. Target standing crop biomass of salal as determined by MCC and actual standing crop biomass grown by salal. Simulation is for an initial planting density of 4440 stems per hectare thinned to 500 stems per hectare at age 13.

OPERATIONAL SIGNIFICANCE

The final model will provide a tool to aid forest managers in determining when measures to reduce salal are a useful management technique and how these measures can be applied in a cost-effective manner. The model will also aid foresters in evaluating the consequences of thinning on salal growth and competition with the crop tree.

REFERENCES

Bunnell, F.L., R.S. McNay, and C.C. Shank. 1985. Trees and snow: the deposition of snow on the ground - a review and quantitative synthesis. B.C. Min. Environ. and Min. For., Victoria, B.C. IWIFR-17.

Mitchell, K.J. and I.R. Cameron. 1985. Managed stand yield tables for coastal Douglas-fir: initial density and precommercial thinning. B.C. Min. For., Research Branch, Victoria, B.C.

Reineke, L.H. 1933. Perfecting a stand index for even-aged forests. J. Agric. Res. 46:627-638.

Vales, D.J. 1986. Functional relationships between salal understory and forest overstory. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 138 p.

df et al.: An Interspecific Competition Model for Young Douglas-fir Plantations of Coastal Oregon and Washington

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In 1987, the CRAFTS (Coordinated Research for Alternative Forestry Treatments and Systems) Cooperative and COPE (Coastal Oregon Productivity Enhancement) Program at Oregan State University jointly initiated a study to develop a growth model for young Douglas-fir (*Pseudotsuga menziesii*) plantations. It was recognized that such a model was needed to quantify the impact of competing vegetation and release treatments on the long-term development of Douglas-fir stands. This project is also directed at identifying gaps in the existing data and guiding future research.

A preliminary version of the model called **df et al.** (Douglas-fir and others) has been completed for five species – Douglas-fir, red alder (*Alnus rubra*), salmonberry (*Rubus spectabilis*), thimbleberry (*Rubus parviflorus*), and vine maple (*Acer circinatum*). This version predicts the height and cover development of any combination of these species on a circular 1/300-acre (0.001-ha) plot.

During the past year, **df et al.** was fitted to data gathered by the CRAFTS Cooperative from several studies to estimate unknown parameters and to test the model's predictive ability. Statistical evaluation revealed that the model accounted for much of the variation in the data.

The current version of **df et al.** can simulate the effects of competing vegetation in a coastal Douglas-fir plantation for the first 20 years. For example, dominant Douglas-fir can attain a height of 49 ft (14.9 m) at age 20 (Figure 1A) and crown closure at age 12 (Figure 1B) in the absence of competition from woody vegetation. If salmonberry dominates the site in the first year, Douglas-fir attain a height of 42 ft (12.8 m) by age 20, and crown closure is delayed until age 15. If red alder also invades, Douglas-fir can attain a height of only 17 ft (5.2 m), and crown closure is delayed beyond age 20. These simulations assume a site index (total height at breast-height age 50) of 125 ft (38.1 m) and a Douglas-fir density of 300 trees per acre (121 trees per hectare).

Current efforts are directed at adding functions for Douglas-fir and red alder stem diameter, Douglas-fir mortality, and the impacts of competition from herbaceous vegetation. The model also is being enhanced to include the effects of specific competition release treatments. Plans call for using outputs from **df et al.** as inputs to models for older stands to evaluate the potential long-term economic effects of forest vegetation management.

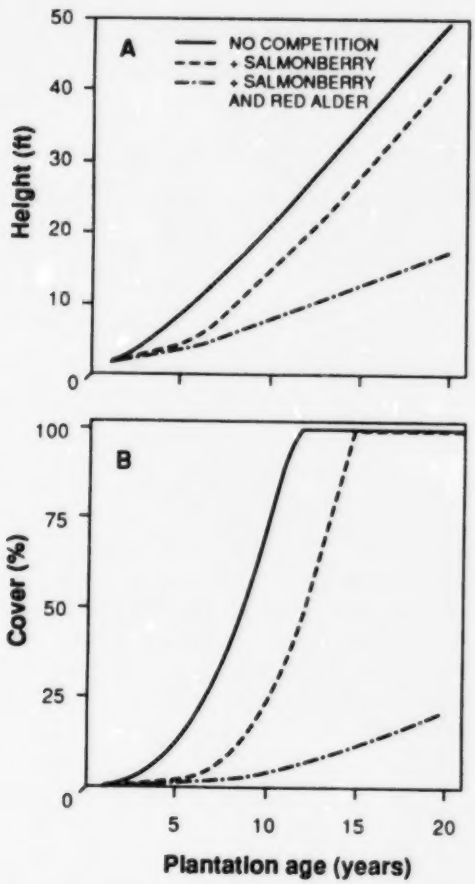

FIGURE 1. Height (A) and cover development (B) of coastal Douglas-fir competing with woody vegetation, as simulated by the current version of **df et al.**

A Water Balance Model as an Aid to the Assessment of Planting Windows

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PROBLEM

Soil water deficits are encountered on many sites in B.C. during parts of the year. Following planting, tree seedlings require 1-2 months of adequate soil moisture to allow sufficient root growth for establishment and subsequent survival. Tools are required to assist foresters in determining when sites may be suitable for planting. These tools will assist in the planning of a planting program, or can be used to examine the suitability of planting conditions, specifically, whether the soil is moist enough to plant. To be effective, any tool must account for the influences of site conditions (e.g., soil and vegetation), plant requirements, and weather conditions.

The objective of this research was to produce a simple computer model for predicting the soil water balance of sites, and to develop procedures for interpreting the output of the model in terms of seedling planting windows.

THE MODEL

The model (Spittlehouse and Goldstein 1989) is based on a number of procedures reported in the literature. Development was funded through FRDA Project 2.03/3.37 and the B.C. Forest Service. Data required to run the model include:

- site – latitude, longitude, elevation, slope, aspect, soil texture, stone content, soil depth, vegetation classification, vegetation cover; and
- weather – maximum and minimum air temperature, rainfall.

Ideally, the weather data, particularly rainfall, should be obtained near to the site of interest. The farther away the monitoring station, the lower the reliability of the prediction. The model uses the above information to calculate the daily transpiration from the vegetation and evaporation from the soil surface. The moisture conditions in the seedling root zone are then estimated by the model.

COMPUTER DEMONSTRATION

When the model is used for real-time assessment, a simulation is updated daily (or weekly) using fire-weather station data. The model then calculates three scenarios that project soil moisture conditions for 45 days from the current date (Figure 1). These are for high, medium, and low rainfall regimes. An

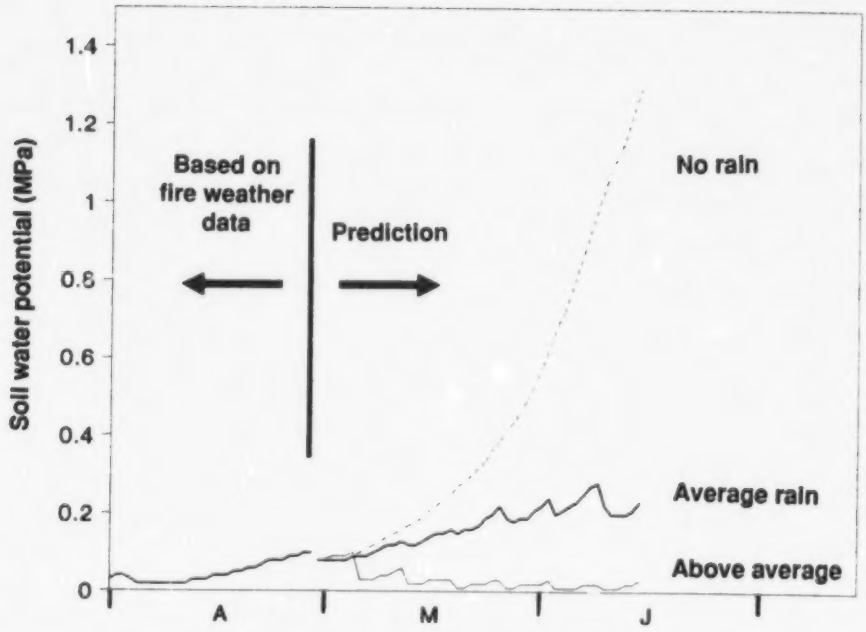

FIGURE 1. Real-time assessment of seedling root zone (0-0.2 m) soil moisture potential. Data from the fire-weather network (temperature and rainfall) were used to determine conditions at the end of April. Projection of future conditions are made for three rainfall scenarios: no rainfall (dashed line), average rainfall for the area (heavy solid line), and well above-average rainfall (light solid line).

assessment of "historic" rainfall records can be used to determine the probability of each situation occurring. Users can then decide the risk they are willing to accept in proceeding with planting. The expected response of planted seedlings can also be estimated. The projections can be re-assessed daily or weekly using fire-weather data.

Site assessment can also be performed using the model. This format is used to predict how sites with different soil textures and levels of vegetation cover dry out (Figure 2). The length of the planting window can then be predicted using the simulated water potential and knowledge of seedling moisture requirements (Figure 3). The horizontal bars indicate the spring and fall planting windows. Early closing and late opening of the planting window result because the site being considered has a coarse-textured gravelly soil and low summer rainfall. If the competing vegetation had begun to senesce by the end of August, September depletion of soil moisture would be reduced and the fall planting window would be open at the beginning of September.

Long-term weather records can be used to assess the probability of occurrence of various moisture regimes (Spittlehouse and Childs 1990). A simplified form of the model in a Lotus spreadsheet has been developed for situations where generalized predictions are required. This form of the model is also a useful educational tool (Spittlehouse and Stathers 1989).

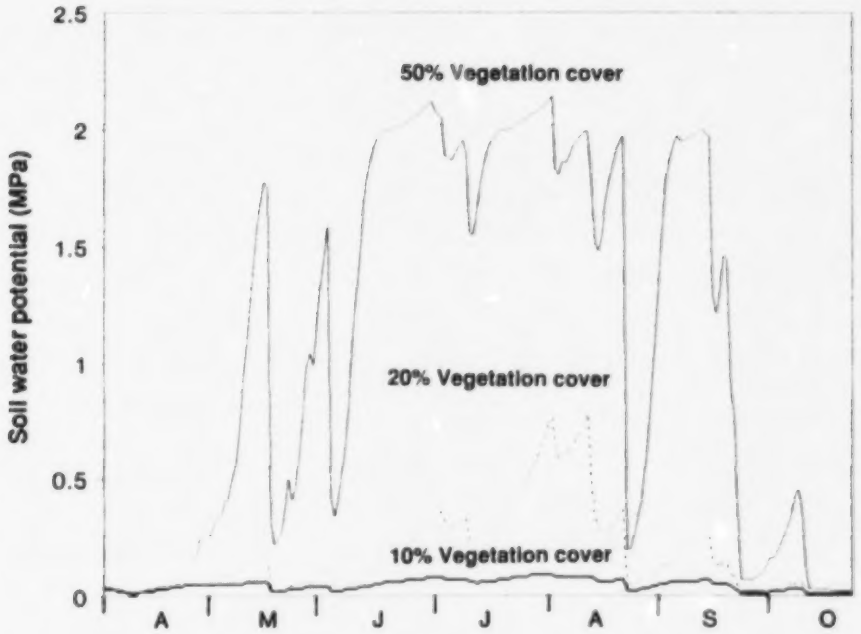

FIGURE 2. Simulation of the influence of three levels of vegetation cover on the soil water potential in the seedling root zone (0 to –20 cm).

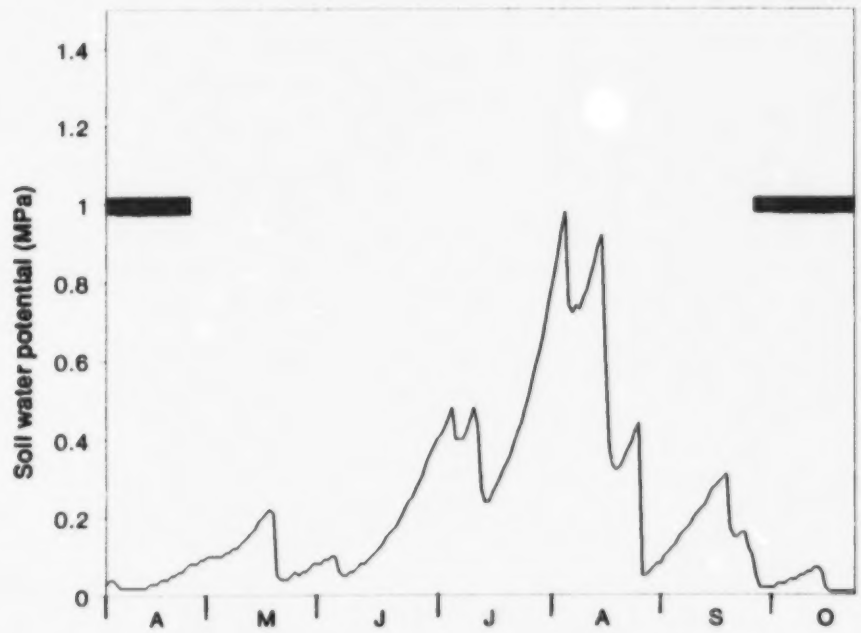

FIGURE 3. Estimation of the planting window for the 20% vegetation cover scenario shown in Figure 2. The horizontal bars indicate the spring and fall planting windows.

REFERENCES

Spittlehouse, D.L. and S.W. Childs. [1990]. Soil moisture after site preparation. *In* Sustained Productivity of Forest Land. Proc. 7th. N. Am. Soils Conf., Vancouver, B.C. In press.

Spittlehouse, D.L. and M.J. Goldstein. 1989. Modelling soil water availability for seedling establishment. *In* Climate applications in forest renewal and forest production. D.C. MacIvor, R.B. Street, and A.N. Auclair (editors). Environ. Can., Atmos. Environ. Serv., Downsview, Ont., pp. 117-126.

Spittlehouse, D.L. and R.J. Stathers. [1989]. Seedling microclimate. B.C. Min. For., Victoria, B.C. Land Manage. Rep. 65. In press.

VegPro: A Forest Vegetation Management Prescription Optimization and Information System

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Successful reforestation of newly harvested sites often requires that competition from associated woody and/or herbaceous vegetation be managed. After current or potential levels of competition from such vegetation are judged to limit the survival or growth of planted conifers, selection of an appropriate treatment is considered. Selecting the best treatment, however, can be a difficult task when the forester is considering the species composition, number of available treatments, treatment costs, and variable treatment efficacy among plant species.

To assist foresters with the process of making vegetation management prescriptions, the CRAFTS Cooperative at Oregon State University has recently developed an interactive computer program called VegPro (Forest Vegetation Management Prescription Optimization and Information System). VegPro contains current information on herbicides and manual treatments for forest vegetation in the Pacific Northwest.

To use the program, the target species composition, desired conifer species, and treatment costs are entered for a specific forest site being considered for treatment. VegPro then uses a treatment efficacy data base and user-determined selection criteria to choose the best treatment. Available treatments are ranked according to the amount of vegetation remaining after treatment, treatment cost, and cost efficiency. VegPro can handle site preparation, release, and individual-plant treatments for (1) deciduous woody vegetation in the Coast and Cascade ranges, (2) mixed sclerophyll vegetation in the southwestern Oregon and northern California, and (3) herbaceous vegetation. Users also may customize the data base to conform with local experience, or update the data base with information on new treatments.

In addition, a window containing a detailed description of each treatment can be accessed. Specific information for each herbicide treatment includes rate, carrier, timing, and adjuvants. The herbicide's manufacturer, chemical name, mode of action in the plant, toxicity, and environmental characteristics are also provided. The current registration status for each treatment in Oregon, Washington, and California and specific comments related to the use of each treatment are also included. For users new to the field, a window containing a glossary of forest vegetation management terms can be accessed.

When a treatment decision has been made, a detailed printout of all pertinent information can be provided. This printout can serve as documentation for selecting a vegetation management prescription for a specific site.

Oregon State University has recently licensed VegPro to a commercial software company for distribution and support. Details about the price and release date are available from Symbio Technologies by mail (2396 NW Kings Boulevard, Suite A, Corvallis, OR 97330) or phone (503/758-5282).

DISCUSSION GROUPS
General Issues

Fourth Vegetation Management Workshop
General Discussion Group

The question put to about 100 forest operations staff and researchers participating in the Workshop was "What are the most important issues in vegetation management?"

Twelve groups of 8-10 people discussed these issues for about an hour and presented their summaries to the general assembly.

The following issues and needs related to public concerns, current vegetation management practices, and new approaches to vegetation management were identified.

Public concerns

Issues

- public concern about forest management practices (including vegetation management).
- polarization of public vs forest industry and Forest Service.
- threat to forest management by future litigation.

Needs

- increased public involvement in forestry decision-making.
- a resource management planning process that considers other resource values in the economic analysis.
- a team approach to resource management that involves all resource management agencies.
- more Forest Service staff and resources to provide information to the public about forestry practices.

Current Vegetation Management Practices

Issues

- future restrictions on the use of chemicals and other vegetation management tools.
- lack of a clear government policy or direction on the use of chemicals for vegetation management.

Information Needs

- ecosystem-specific vegetation management prescriptions and techniques.
- costs and benefits of different treatments.
- ways to prevent vegetation management problems.
- successional patterns and plant biology.
- ways to determine when competition is a problem and what the nature of that competition is.
- site-specific information so that vegetation control is only used when it is essential.
- toxicological effects of herbicides.
- potential long-term effects of vegetation management on site degradation.

New Approaches to Vegetation Management

Needs

- information on costs and benefits of alternatives to current practices, such as pre-harvest treatments to control vegetation; alternative harvesting systems; use of mixed species, mixed wood, and shelterwood; etc.
- market research and the development of new markets for hardwoods.

DISCUSSION GROUPS
Alluvial Coastal

Vegetation Management Planning Exercise: Coastal Alluvial Ecosystems

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Alluvial sites occupy valley systems along the entire length of the British Columbia coast and represent some of the most productive forest land in the Vancouver Forest Region. As a result of very vigorous post-logging growth of deciduous trees and shrubs, and because of inundation and erosion brought about by relatively unpredictable flooding, alluvial sites are also among the most difficult sites to regenerate to coniferous forest plantations. The sites also are the interface between forestry and fisheries resources, and they also provide critical wildlife habitat for many of our most important wildlife species, especially bears, ungulates, and waterfowl. In addition to these resource interactions, alluvial sites are important for maintaining the hydrological integrity of watersheds, and as recreational sites. For all of these reasons, forested alluvial ecosystems present an important and complex challenge in integrated resource management for the forest manager.

In this vegetation management planning exercise, participants were presented with seven forest regeneration options for a high bench alluvial site in a typical coastal valley system. The options vary considerably in the timber products they produce and in their potential impact on non-timber resources. From the information provided, you will attempt to rank the options (or create your own) for their:

a. silvicultural reliability, productivity, and feasibility;

b. value strictly for non-timber resources; and

c. value for optimizing both timber and non-timber values.

There is, of course, no "correct" answer, since rankings will vary according to factors such as your timber supply objectives or your assessments of the various impacts of applying the different options to the site.

The object of the exercise is to have participants systematically consider and discuss the integration of timber production with non-timber resources on forested alluvial sites. An analysis of this nature could prove useful for organizing priorities during preparation of pre-harvest silvicultural prescriptions or provide input for a 5-year management working plan. During this session, the following questions were considered:

1. What is the best resource usage of forested alluvial sites (timber or non-timber) or can all resource users be satisfied through carefully integrated forest management?

2. What suggestions would you have for incorporating resource management on this site into a resource management plan for the entire watershed?

3. Given the dynamic nature of alluvial sites, do you think considerable risk to non-timber resources still exists, even if fisheries-forestry guidelines were followed to the letter on this site?

4. Do we have enough information to make informed management decisions on the impact of silvicultural treatments on non-timber resources? Will we ever have?

SCENARIO AND OVERVIEW

As a preliminary scenario, the following parameters were considered for the exercise:

1. The site has been logged the previous winter by high lead and all timber has been removed.
2. Recommendations outlined in the Coastal Fisheries Forestry Guidelines (1988, Second Edition) have been followed so that effective buffers remain along watercourses and backwaters, road and landing layout is appropriate, and all felling and yarding has been carried out according to the guidelines.
3. Management of the stand is part of an integrated resource management plan for the entire watershed. For example, assume that there are sufficient similar old-growth stands left in adjacent areas in the watershed so that clearing this stand does not represent a critical loss of wildlife habitat.

SITE DESCRIPTION

Site Type: CWHdm/Cw-Ss-Devil's Club/typic

Site Quality: SMR - fh/fresh; SNR - rich

Recommended Species: Cw, Bg, (Fd), Ac

CSSC Soil Classification: Humic regosol - **Humus Form:** vermimull

Soil Texture: coarse sand at depth fining upwards to sandy loam at the surface

Soil Depth: > 2 m

Flooding Frequency: site can be expected to be flooded below ground about every 5 years and above ground about every 10 years

Site Stability: Cw and Ss removed from site were greater than 300 years old so site is relatively stable under conditions of forest cover. (It is not well understood how forest clearance affects alluvial site stability.)

Wildlife: site is well used by elk, deer, and black and grizzly bear

Fisheries: resident coho population in adjacent river; seasonal spawners present in sloughs and backchannels within and adjacent to site

Recreation: site provides access to river for fishermen

TABLE 1. Three black cottonwood regeneration options

	1. Black cottonwood (Extensive)	2. Hybrid poplar (Extensive)	3. Hybrid poplar (Intensive)
Site preparation	none	drum scarification	scarification, stumping chemical?
Planting	none (natural regeneration)	hybrid poplar whips	hybrid poplar cuttings
Stand tending	fill plant hybrid whips	fill plant hybrid whips	weed control for 5 yr - (machine/chemical)
Rotation age	30-40 yr[a]	25-35 yr[a]	15-20 yr[a]
Stocking at rotation	250-300 stems/ha[a]	400 stems/ha[a]	600 stems/ha[a]
Net yield at rotation	250-300 m^3/ha[a]	300-600 m^3/ha[a]	300-600 m^3/ha[a]

[a] Based on yield data provided by Scott Paper Ltd.

TABLE 2. Two conifer-black cottonwood (nurse tree) regeneration options

	4. Cw/Bg/Ac (Extensive)	5. Cw/Bg/Ac (Intensive)
Site preparation	none	scarification
Planting	- shovel plant BR jumbo Cw/Bg - browse protection	- shovel plant BR jumbo Cw/Bg and rooted hybrid poplar whips - browse protection
Stand tending	- fill plant Cw/Bg - free conifers by manual brushing around trees - girdle/H&S hardwood overstory	- fill plant Cw/Bg
Rotation age	Cw/Bg: 80+ yr	Ac: 15-20 yr Cw/Bg: 80+ yr
Stocking at rotation	Cw: 130 stems/ha[a] Bg: 75 stems/ha[a] Total: 205 stems/ha	Ac: 200 stems/ha[b] Cw: 146 stems/ha[c] Bg: 85 stems/ha[c] Total: 431 stems/ha
Net yield at rotation	Cw: 277 m^3/ha Bg: 360 m^3/ha Total: 637 m^3/ha	Ac: 200 m^3/ha[b] Cw: 312 m^3/ha[c] Bg: 404 m^3/ha[c] Total: 916 m^3/ha

[a] Based on yield for pure plantations and decreased by 1/3 to account for lower final stocking.

[b] Based on hybrid poplar growth and yield (option 2) and accounting for lower final stocking than pure plantation.

[c] Based on yield for pure plantations and decreased by 1/4 to account for lower final stocking.

TABLE 3. Two conifer plantation regeneration options

	6. Cw/Bg	7. Fd
Site preparation	- slashburn	- chemical - slashburn
Planting	- shovel plant BR jumbo Cw/Bg - browse protection	- shovel plant BR jumbo Fd - browse protection
Stand tending	- fill plant Cw/Bg - apply glyphosate at 2 and 9 yr	- fill plant Fd - apply glyphosate at 2,5, and 9 yr
Rotation age	70+ yr	60+ yr
Stocking at rotation	Cw: 195 stems/ha[a] Bg: 113 stems/ha[a] Total: 308 stems/ha	126 stems/ha[a]
Net yield at rotation	Cw: 416 m^3/ha[a] Bg: 538 m^3/ha[a] Total: 954 m^3/ha	780 m^3/ha[a]

[a] Based on British yield tables.

RESULTS OF THE EXERCISE

Mixed planting of cottonwood and conifers (options 4 and 5) was considered to be the most desirable system (six groups chose these). Even though the interplanting systems are more or less untested, most groups thought it important to try to establish conifers on the site and that the interplanting options were the best compromise between timber and non-timber resource values.

The low-impact cottonwood and hybrid poplar scenarios were the next most popular and were selected as optimal by two groups. Ease of regeneration, low establishment costs, high diversity and value for wildlife and fisheries, and site stability were cited as the main reasons for selecting the cottonwood options. Most groups thought the intensive hybrid poplar option resulted in a low-diversity ecosystem and that costs could not be justified in a remote valley such as this one. Costs, lack of diversity, use of chemicals, low stability due to slow site occupation, browsing problems in conifer plantations, and problems with getting a hot slashburn were cited as the main reasons for rejecting pure conifer options (options 6 and 7).